5-1-1976

Distribution of Relative Abundance of Potential Prey of Spotted Sandpipers (Actitis Macularia L.) on Little Pelican Island, Leech lake, Cass Co., Minnesota

Donald Louis Rubbelke

DISTRIBUTION AND RELATIVE ABUNDANCE OF POTENTIAL PREY OF SPOTTED SANDPIPERS (ACTITIS MACULARIA L.) ON LITTLE PELICAN ISLAND, LEECH LAKE, CASS CO., MINNESOTA

by
Donald Louis Rubbelke

Bachelor of Science, University of North Dakota, 1973

A Thesis

Submitted to the Graduate Faculty

of the

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for the degree of

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1976

This thesis submitted by Donald Louis Rubbelke in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

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Department Biology

Degree Master of Science

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Signature Donald L. Rubbelke

Date 4-15-76

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ABSTRACT

Potential prey items of spotted sandpipers (Actitis macularia L.) were sampled during the summer of 1974 on Little Pelican Island, Leech Lake, Cass County, Minnesota. Most abundant terrestrial food items were Diptera of the families Chironomidae and Sciaridae. Most abundant aquatic organisms were cladocera, copepods, and amphipods of the class Eucrustacea. Three large hatches of insects occurred. The first, during the last week of May, was predominantly midges (Chironomidae). The second and the largest occurred during the last week of June and the first week of July. Mayflies (Heptageniidae and Ephemeridae) were most abundant and comprised the majority of biomass during that period. Two or three midge species were also abundant. Caddisflies (Trichoptera) composed the third hatch in the last week of July. Distributions of aquatic and terrestrial potential prey items were wind dependent. Wind velocities over 10 mph greatly reduced availability of potential prey items in exposed areas. Wind direction and vegetational characteristics determined trap success of each area--the interaction of which contributed to highly variable accumulations of potential prey within sheltered areas. Birds congregated in areas of highest food densities and appeared opportunistic in feeding behavior. Nest initiation dates closely followed the first hatch--12 of 14 females initiated nests within six days of the hatch. Projected

hatch dates indicated that chicks of initial nests would have appeared just prior to the second major hatch of the season.

INTRODUCTION

Recent research on avian mating systems has concentrated on environmental factors which influence their evolution and expression. Habitat structure, predation, food availability, and climate are among the more important factors which have been implicated in the evolution of various strategies (Verner, 1964; Verner and Willson, 1966; Lack, 1968; Orians, 1969; Crook, 1970).

In a recent review, Pitelka, Holmes, and MacLean (1974) classify shorebird breeding strategies as monogamous, serially polygamous, polygynous, and promiscuous. The serially polygamous category includes sequential polyandry reported for the spotted sandpiper, Actitis macularia (Hays, 1972; Oring and Knudson, 1972). However, despite the fact that polyandry has long been recognized as a unique mating strategy, attempts to describe environmental correlates responsible for its evolution and/or expression have been wanting.

In studies of two localized populations of spotted sandpipers, Oring and Knudson (1972) present the idea that lability is an important adaptive aspect of social systems. They found that breeding densities, incidences of polyandry, territory sizes, and aggressive levels varied markedly between a population on Little Pelican Island, Leech Lake, Cass Co., Minnesota, and a mainland population at LaSalle Lagoon,

Itasca State Park, Clearwater Co., Minnesota. Subsequently, Oring (Pers. Comm.) has found these population characteristics to vary greatly from year to year on Little Pelican Island. Because there are no available studies dealing with environmental correlates of polyandry evolution, and because spotted sandpipers are known to vary in their degree of polyandry relative to gross environmental differences, this species is ideal for studying mating system-environment interactions.

Food availability in space and time has been cited repeatedly as a key resource in the determination of spacing and mating systems. Energy resources not only influence spacing patterns (Holmes, 1970, 1971), but may lead to early departures of one sex from the breeding ground (Pitelka, 1959; Höhn, 1967; Parmelee, et al., 1968; Nettleship, 1973, 1974) thus reducing competition between adults and young. At the same time, such departures automatically influence male-female relations. In the absence of adequate energy and nutrient resources, breeding may be altogether aborted. Species and populations utilizing food resources which fluctuate greatly, employ opportunistic mating strategies (Graul, 1973). Studies correlating food availability with spacing patterns and mating systems are thus essential if we are to understand how various strategies have evolved and what mechanisms control their expression.

My objectives were to determine relative abundance and distribution of potential prey of spotted sandpipers on Little Pelican Island, Leech Lake, Cass Co., Minnesota. This study is meant to lay the

groundwork for long-range correlations of spacing patterns, mating systems, and potential food distribution.

DESCRIPTION OF STUDY AREA

Little Pelican Island is a two-hectare island just south of Pelican Island, 7-8 km from the shoreline of Leech Lake, Cass Co., Minnesota. Its open sandy beaches grade into semi-open areas of low-lying herbaceous cover which in turn grade into dense woods (Fig. 1). A cattail marsh extends east-west through the north end of the island.

Insect densities were monitored in five areas:

1) Area A, located on the southeast part of the island, is characterized by the largest expanse of semi-open and open beach (at least 20 m wide). Beach vegetation follows a number of distinctive ridges which parallel the water's edge. Vegetation height varies from tall trees (approx. 15 m) near the island interior to saplings (1-2 m) which follow the beach ridges. The most common plants are:

Trees and Shrubs	Ground Cover
Populus deltoides	Lathyrus japonicus
Salix spp.	Asclepias purpurascens
Ulmus americanus	Apocynum cannabinum
Fraxinus pennsylvanicus	Carex spp.
Acer negundo	Bromus sp.
Vitus sp.	Verbena hastata

Figure 1. Aerial photograph of Little Pelican Island, Leech Lake, Cass County, Minnesota.

2) Area B, on the northeast side of the island, has a rocky shoreline and a relatively narrow open beach. Fairly sparse vegetation on the semi-open areas of the beach rapidly gives way to dense undergrowth as one proceeds toward the interior. Willows (Salix spp.) of 4-5 m surround the open and semi-open habitats and provide excellent shelter from wind. The most common plants are:

Trees and Shrubs	Ground Cover
Salix spp.	Carex spp.
Fraxinus pennsylvanicus	Bromus sp.
Ulmus americanus	Urtica dioica
	Convolvulus sepium

3) Area C, located just to northeast of area B on the opposite side of the willows, is primarily grass and sedge habitat with a cattail marsh bordering the south edge. Open beach is minimal (1-2 m). The area is bordered on the east by willows of approximately 4-5 m and on the south by a mature stand of American elm (Ulmus americanus) at least 12 m in height. The most common plants are:

Trees and Shrubs	Ground Cover
Salix spp.	Carex spp.
Ulmus americanus	Bromus sp.
Fraxinus pennsylvanicus	Phragmitis communis
	Urtica dioica
	Typha latifolia

4) Area D, located on the extreme north end of the island, is characterized mainly by low-lying annuals and perennials. Woody vegetation is minimal with one small clump of willows on the east end and several large elms to the south. A sheltered cove borders the northeast edge of the area with a cattail marsh delimiting the south edge. The most common plants are:

Trees and Shrubs	Ground Cover
Salix spp.	Carex spp.
Ulmus americanus	Bromus sp.
	Typha latifolia

5) Area E, on the southwest side of the island, is characterized by dense vegetation. This area is bordered on the north by the large cattail marsh and on the east by a large clump of smooth sumac (Rhus glabra) bushes (2-3 m). Just interior to the sumac bushes, trees 4-5 m high extend into the island interior. The most common plants are:

Trees and Shrubs	Ground Cover
Salix spp.	Carex spp.
Rhus glabra	Bromus sp.
Ulmus americanus	Typha latifolia
	Sagittaria latifolia
	Polygonum spp.
	Impatiens sp.

The areas vary in their degree of exposure to winds as shown in Table 1.

TABLE 1

RELATIVE EXPOSURE OF FIVE STUDY AREAS
TO DIFFERENT WIND DIRECTIONS

Area	N	W	S	E
A	+	+	+++	+++
B	+	+	+	++
C	+++	++	+	+
D	+++	+++	+	+
E	++	+++	+++	+

+=minimal

++=moderate

+++=maximal

Each of the five areas was subdivided into five trap sites representing five different habitat types. Trap site descriptions were as follows: (1) Open beach--open sandy beach at least two meters from the nearest vegetation and within four meters of the water edge. Trap placement was as close to the water edge as wave action would allow. (2) Semi-open--sites located in areas of at least 50% open sand with vegetation consisting of herbaceous cover not over 1 m ht. (3) Grassy--sites located in patches of grass and/or sedge. (4) Semi-open with saplings--sites qualitatively very similar to sites 2, the distinction

being the presence of woody vegetation of 5 m ht or less within two meters of the trap site. (5) Wooded--sites located under woody vegetation of 5 m ht or more.

MATERIALS AND METHODS

The relationships between weather, invertebrate populations, cover, and spotted sandpiper foraging behavior were studied from 12 May to 1 August 1974. Methods and materials used throughout the summer were as follows:

Weather

Temperature and humidity were recorded continuously after 30 May with an automatic recording hygrothermograph. Wind direction and velocity were recorded with a hand-held anemometer. Wind readings were always taken on the windward side of the island. Whenever a significant change in direction and/or velocity occurred, the time of change was noted. These readings were used to obtain resultant wind directions and velocities. Precipitation was measured with a standard cylindrical rain gauge. Weather records from 1970 to 1974 were obtained from the U.S. Department of Commerce, Environmental Science Services Administration, Ashville, North Carolina.

Terrestrial Insect Sampling

Cylindrical insect sticky traps were constructed similar to the design of Broadbent (1948). Two-pound coffee cans were painted "garden green" and wrapped with 13 cm wide strips of green "Durlux" polyethylene

plastic (Fig. 2). The plastic was coated with a thin layer of Bird Tanglefoot resin (The Tanglefoot Co., Grand Rapids, Michigan).

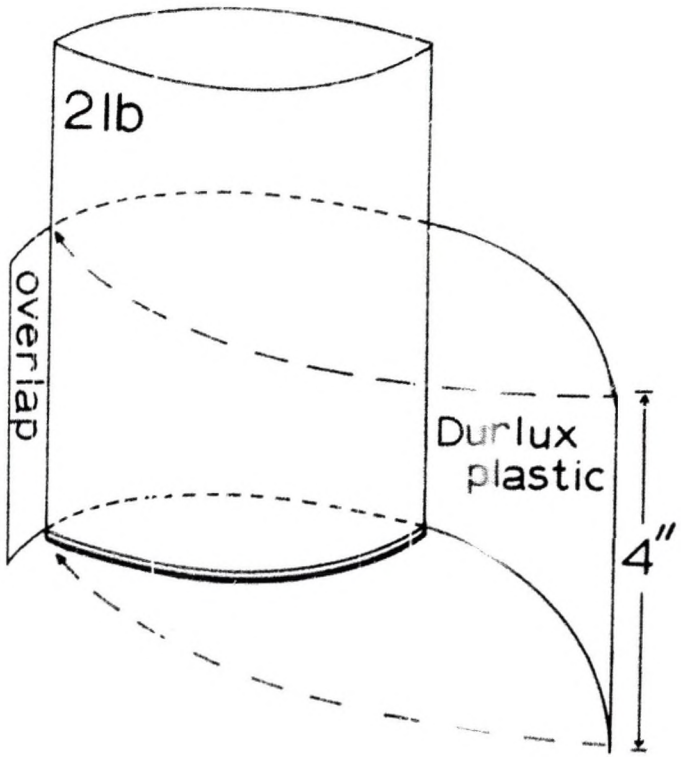
Sticky traps are superior to most sampling devices for determination of relative arthropod abundance because of the continuous nature of the catch, and the ease with which trap surface is standardized (Southwood, 1966; MacLean and Pitelka, 1971). Cylindrical traps are advantageous because of their omnidirectional catching ability and constancy of catch in winds of 2-10 mph (Taylor, 1962).

Five sample areas (A-E) were chosen representing five different wind exposure angles. Within each area, five trap sites (1-5) were chosen, each representing a different habitat type (Fig. 3 and 4). All traps were placed in an enclosure of one-inch mesh chicken wire to prevent disturbance. Intervals between sampling periods were two days with the exception of a five-day interval from 21 to 27 May and a three-day interval from 13 to 17 June. Exposure periods were 48 $\pm$ 1 hours with the exception of the first and second exposure periods which were five and four days in length, respectively. For cases where exposure periods exceeded 48 $\pm$ 1 hours the percentage of the total trap catch proportional to 48 hours was used for statistical analysis. Traps were transported to and from trap sites in carriers constructed from three-pound coffee cans to prevent entrapment of insects and debris (Fig. 2).

Insects were removed from traps by dissolving the resin with no. 1 grade fuel oil and filtering with a standard kitchen strainer (no. 12 mesh). Insects were washed with 90% ethyl alcohol and preserved in 70% ethyl alcohol.

Figure 2. Design of sticky traps and carriers.

STICKY TRAPS & CARRIERS



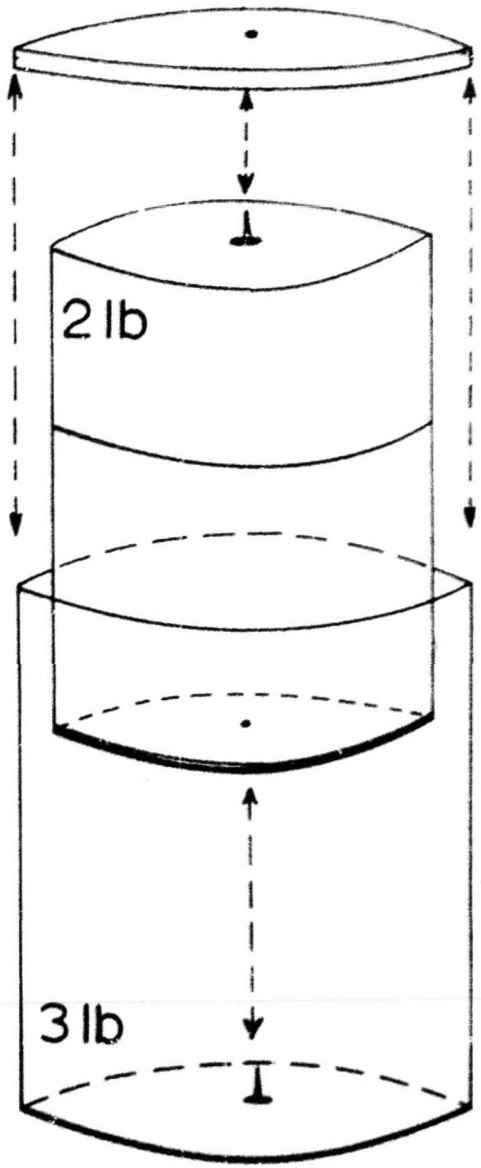


Figure 3. Map of sticky trap areas (A-E), sites (1-5), and shoreline sample area locations (I-V).

LITTLE PELICAN ISLAND

STICKY TRAP AREAS (A-E), SITES (1-5), AND SHORELINE SAMPLE LOCATIONS (I-V)

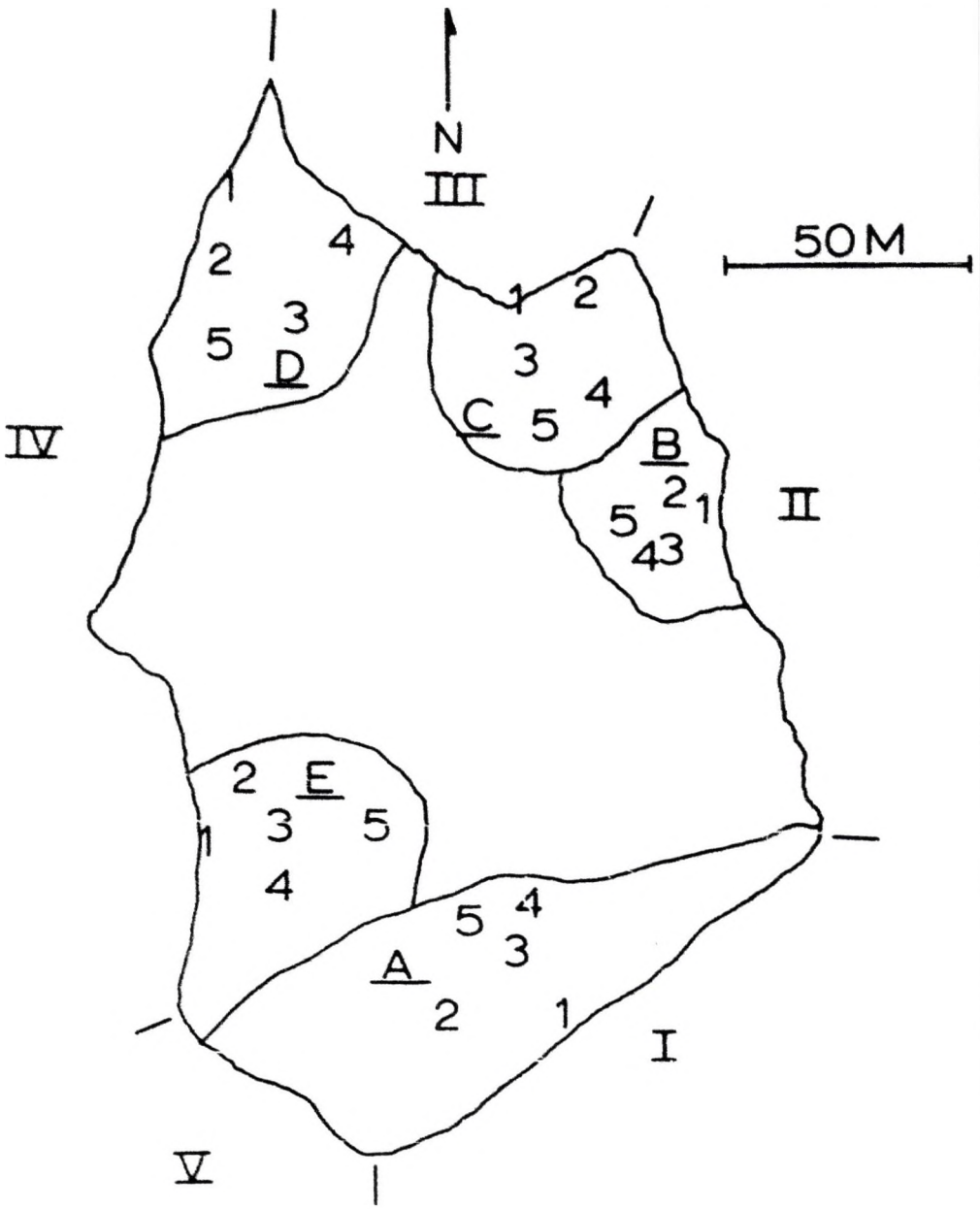
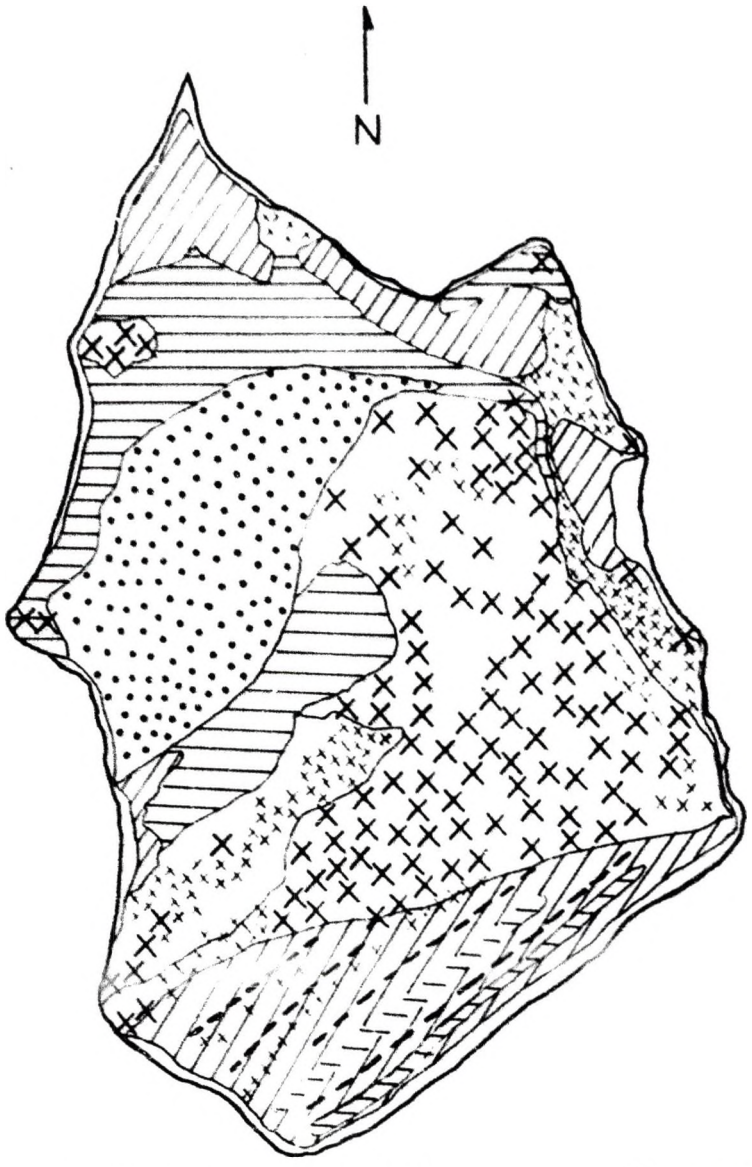


Figure 4. Major habitat types, Little Pelican Island.

LITTLE PELICAN ISLAND HABITAT TYPES



A total of 2,500 insects was identified from sticky traps for determination of family composition and relative abundance of insect groups. Samples were placed in a large petri dish overlying a numbered grid. A table of random numbers was used to pick ten insects from each site on ten sample dates. The first three and thereafter every other sampling period was used for this compositional analysis.

Dry weights were determined for all sticky trap samples. Insects were separated from debris by hand, dried at 35° C for 48 hours, and weighed to the nearest .01 g.

Aquatic Invertebrate Sampling

Samples of shoreline invertebrates were taken concurrently with sticky trap exposure periods with the exception of the first two samples which were taken one day before and after sticky trap exposure periods. An attempt was made to sample both days of the sticky trap exposure time but weather conditions sometimes prevented this. After 18 June, shoreline samples were taken on only one of the sticky trap exposure days. The shoreline method involved the use of a 56 cm diameter drum which was dropped three times along each of five shorelines (I-V) representing five different wind exposure angles (Fig. 3). At each drop inner and outer water depths were recorded to allow determination of water volume. Sand enclosed by the sampler was agitated, and a standard aquarium net (no. 10 mesh) pulled through the water in a figure-eight motion 30 times. Net contents were removed and preserved in 70% alcohol.

All organisms obtained by shoreline sampling were isolated from debris and identified. In the case of extremely small organisms (cladocera and copepods), overall numbers were estimated with the use of a grid. Organisms were divided into three size groups (0-5 mm, 5-10 mm, and 10 mm).

Cover Density

Vegetational densities were determined at each sticky trap site on 28 July by photographing a 1 m^2 backdrop through the vegetation. Two pictures were taken at each site, one through the heaviest cover, one through the lightest, and average relative densities determined from 8 x 10 inch prints. Density is expressed as percentage of backdrop hidden from view. Distance to backdrop, height of camera, and diaphragm aperture were standardized. Results were analyzed with sticky trap results of the last three sample periods of July to determine whether trap success was correlated with vegetational density.

Foraging Behavior

Individual birds were captured in mist nets and color-banded to afford individual recognition. It was possible to color band all but three birds on the island.

Morning feeding observations were of one-hour duration and occurred between 0530 and 1030. Scattered observations throughout the day and occasional one-hour observations in the evening (1800 to 2000) complemented morning observations. Foraging pairs were observed during

feeding observations.

Two methods were used to describe feeding behavior: 1) Instantaneous sampling at 15 sec intervals was used to quantify percentage of time engaged in various activities. 2) Total time spent on beach and spent foraging was measured with stop watches. As each bird appeared on the open beach, band combinations and times were recorded. Observations were of continuous feeding--when feeding bouts were interrupted by courtship or other activities, timed measurements were terminated. Total time spent on the beach and total time spent feeding are expressed as percentage of each hour observation period.

Peck rates were calculated for individual birds during continuous feeding bouts. Timed observations, during which peck rates were quantified, were stopped if birds momentarily interrupted feeding bouts by preening, courtship, etc. Peck rates of birds on each beach were combined to give an average reading for a given beach.

RESULTS

Weather Data

Average daily temperatures and humidity levels were calculated from averaged four-hour readings from continuously recorded data on Big Pelican Island (Fig. 5). Temperatures during early May, prior to the time when an automatic recording device was used, commonly dipped to the lower 30's with a low of 32° F recorded on the morning of 15 May. Night time temperatures were typically 14-20° F lower than daytime highs. After 30 May, the lowest temperature recorded was 46° F during a storm on 14 June. Relative humidity levels usually rose to 100% nightly resulting in heavy covers of dew.

Northwest winds were fairly common throughout the summer (Fig. 6). West winds were prevalent during late May and early June while south winds were especially evident during the last week of June and first week of July. Storms with winds over 35 mph were experienced on 14 June and 13 July. Strong northwest and west winds (10-18 mph) were continuous from 25 July to 29 July. Wave action induced by the high winds in the latter period resulted in 2-3 m of shoreline eroding in a matter of hours.

A total of 16.8 cm of rain fell on Big Pelican Island from 30 May to 1 August (Fig. 7). Three-month records (May-July) for two recording

Figure 5. Average temperature and relative humidity, Big Pelican Island, summer 1974.

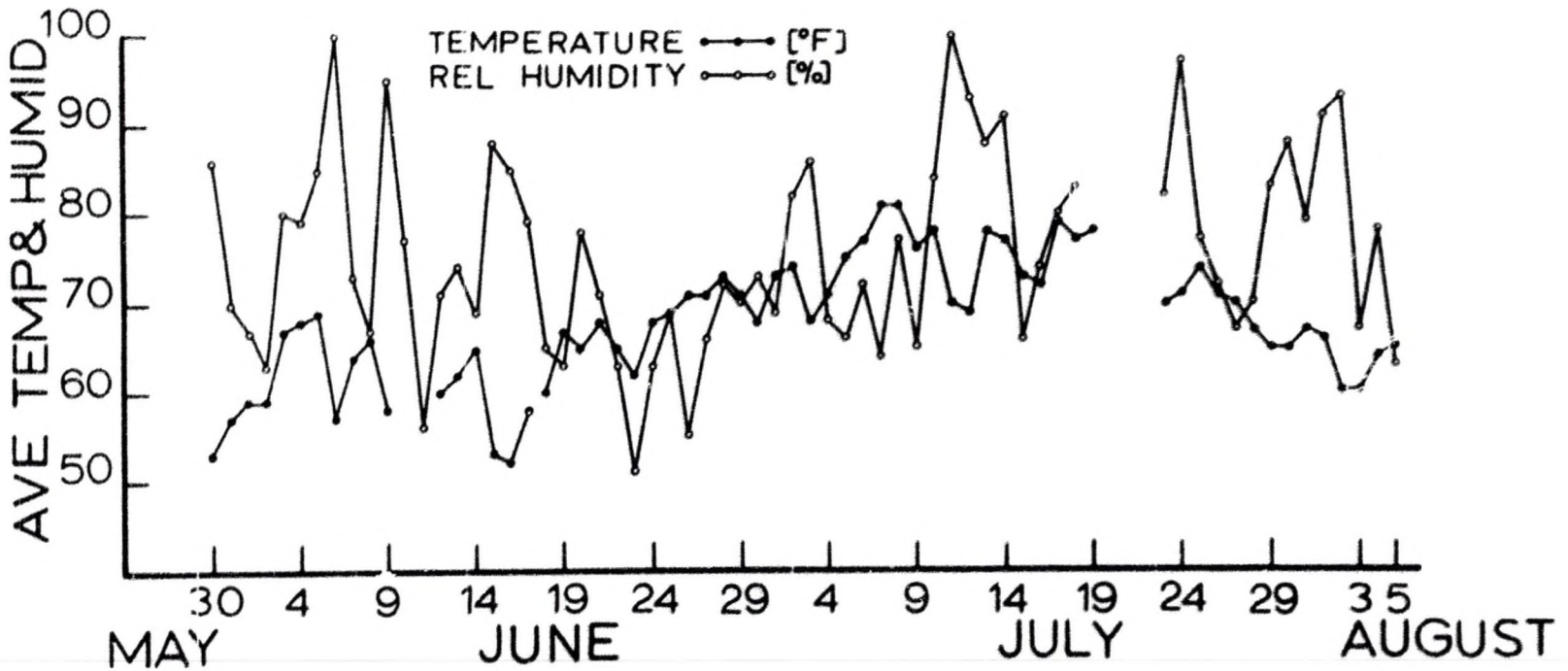
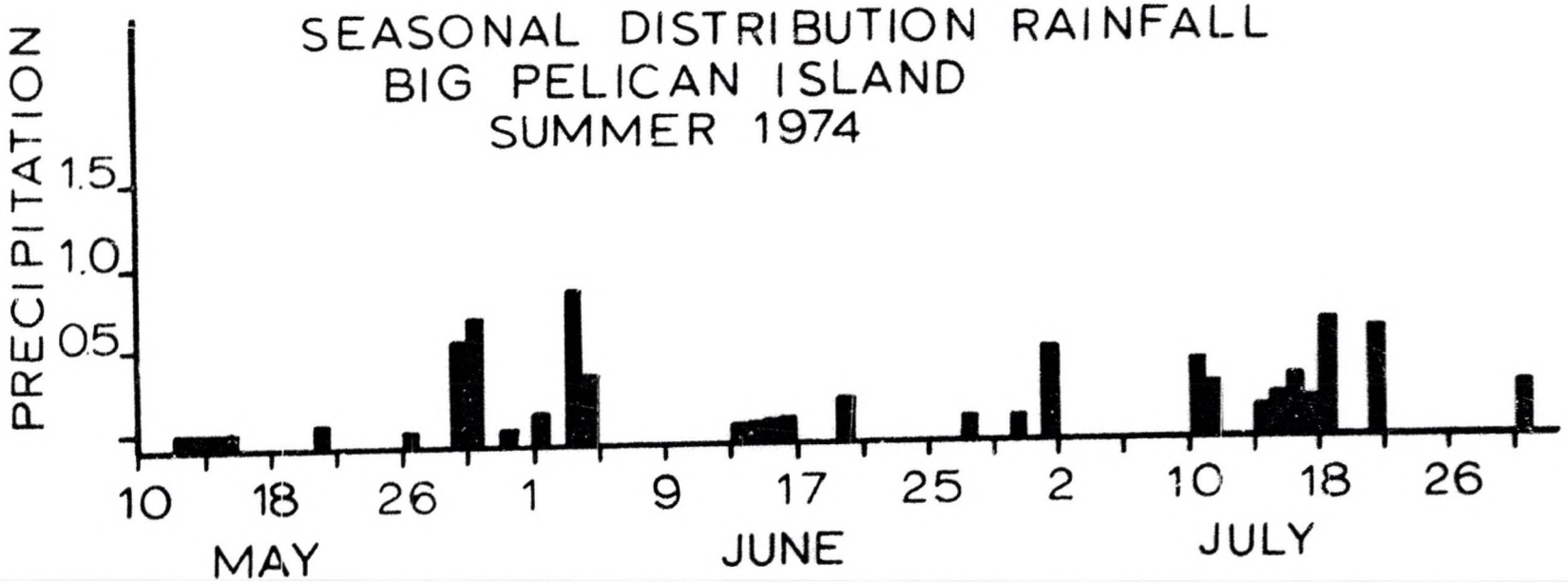

AVE TEMP& HUMID
100
90
80
70
60
50
TEMPERATURE [°F]
REL HUMIDITY [%]
30
4
9
14
19
24
29
4
9
14
19
24
29
3
5
MAY
JUNE
JULY
AUGUST

Figure 6. Wind speeds and directions, Little Pelican Island, mmer 1974.

DIRECTION & VELOCITY (MPH)
N
NE
E
SE
S
SW
W
NW
30
15
0
12
17
22
27
1
6
11
16
21
26
1
6
11
16
21
26
31
MAY
JUNE
JULY

Figure 7. Precipitation records, Big Pelican Island, summer 1974.


SEASONAL DISTRIBUTION RAINFALL
BIG PELICAN ISLAND
SUMMER 1974
PRECIPITATION
1.5
1.0
05
10
18
26
1
9
17
25
2
10
18
26
MAY
JUNE
JULY

stations 16 km to either side of Pelican Island recorded 24.3 and 25.9 cm rainfall. Four and five day rainy spells of intermittent showers occurred from 14-17 June and 16-20 July, respectively.

Insect Sticky Traps

Fifteen arthropod orders including 90 families were collected from Little Pelican Island sticky traps (Appendix I). Diptera accounted for 78% of the total number of individuals caught on sticky traps (Table 2). Of this percentage, half were midges (Chironomidae). Sciaridae accounted for 17% of the total Diptera. Trichoptera and Homoptera each comprised 6% of the total and Hymenoptera 5%.

Sticky trap catches showed three large peaks indicative of three insect hatches during the summer (Fig. 8-14). Totals of sites 1-5 combined (Fig. 13) give the best delimitation of the hatches. The first hatch, during the last week of May, consisted of three or four species of midges (Chironomidae), and at least two species of sciarids (Sciaridae). At least one species of caddisfly (Limnephilidae) was also present, but not in extremely large numbers. The second hatch, by far the largest, occurred during the last week of June and first week of July. At least two species of mayflies (Ephemeridae and Heptageniidae), two or three species of midges (Chironomidae), and two or three species of caddisflies (Helicopsychidae and Hydropsychidae) constituted the majority of the hatch. Ephemeroptera, although only 2% of the total sample composition (Table 2), contributed to the majority of the total biomass present during

TABLE 2

PERCENTAGE CATCH OF PRINCIPAL GROUPS
OF INSECTS CAUGHT ON STICKY TRAPS

Order	Percentage of Total
Diptera	77.56
Chironomidae	38.84
Sciaridae	13.24
Phoridae	5.88
Simuliidae	5.20
Dolichopodidae	2.76
Sphaeroceridae	2.04
Misc. Families	9.60
Homoptera	5.96
Cycadellidae	5.76
Misc. Families	.20
Trichoptera	
Helicopsychidae	2.92
Hydropsychidae	1.92
Misc. Families	.76
Hymenoptera	4.96
Braconidae	1.84
Pteromalidae	1.12
Misc. Families	2.00
Ephemeroptera	2.28
Ephemeridae	1.80
Heptageniidae	.48

Figure 8. Sticky trap results-area A, gm dry weight totals, sites 1-5.

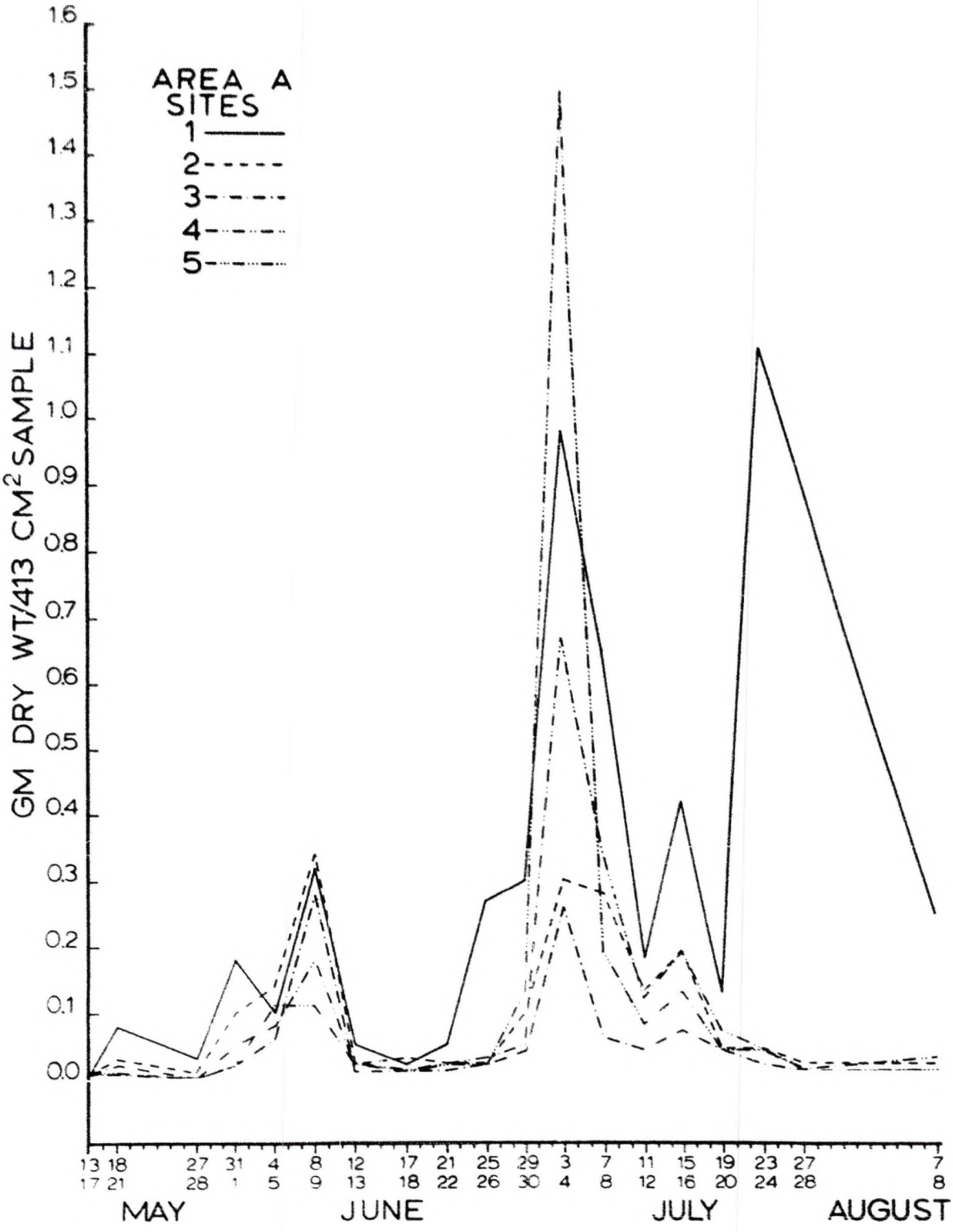

AREA A
SITES
1
2
3
4
5
GM DRY WT/413 CM² SAMPLE
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
13 18 27 31 4 8 12 17 21 25 29 3 7 11 15 19 23 27 7
17 21 28 1 5 9 13 18 22 26 30 4 8 12 16 20 24 28 8
MAY
JUNE
JULY
AUGUST

Figure 9. Sticky trap results-area B, gm dry weight totals, s 1-5.

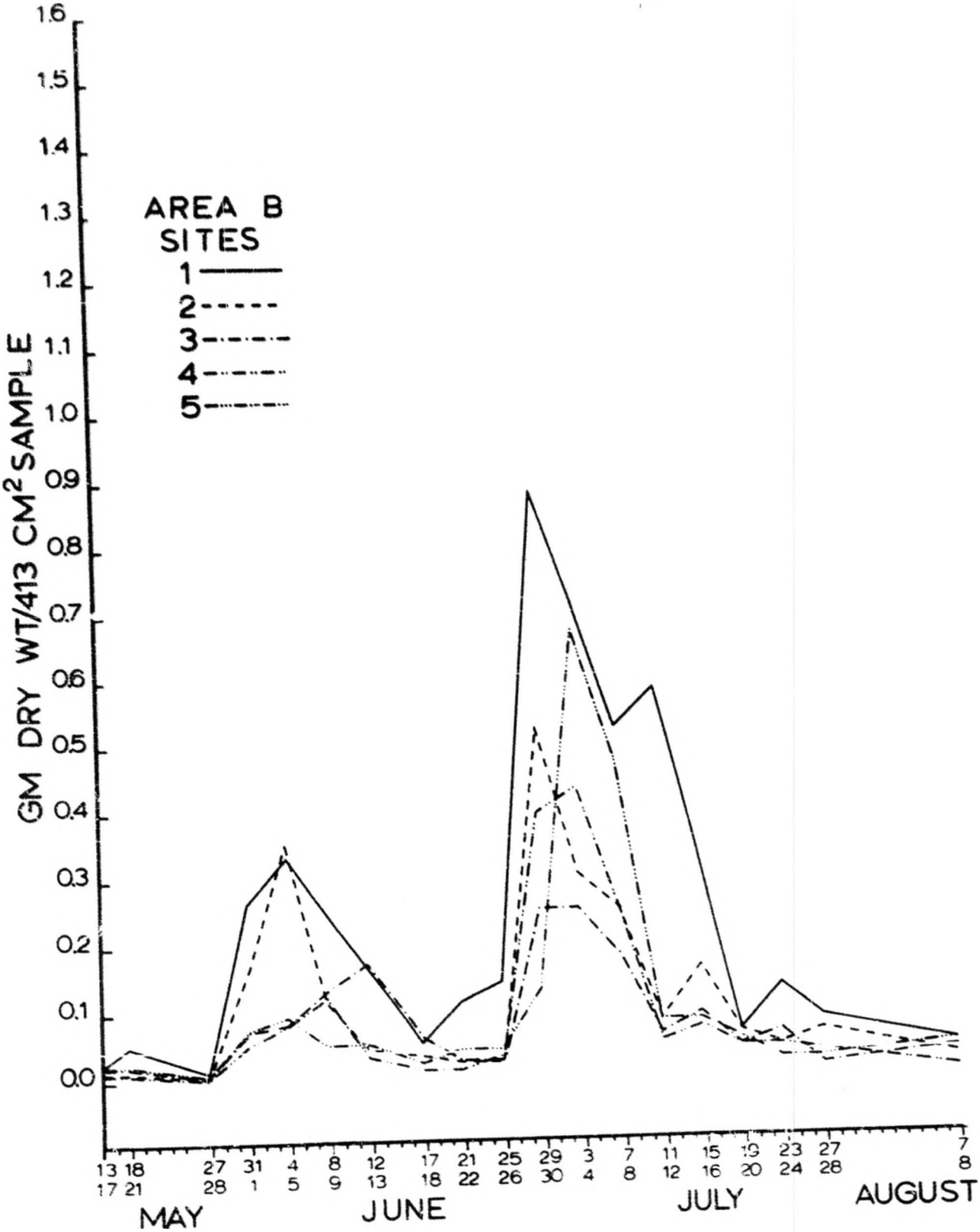

GM DRY WT/413 CM² SAMPLE
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
AREA B
SITES
1
2
3
4
5
13 18
17 21
27 31 4 8 12 17 21 25 29 3 7 11 15 19 23 27 7
28 1 5 9 13 18 22 26 30 4 8 12 16 20 24 28 8
MAY
JUNE
JULY
AUGUST

Figure 10. Sticky trap results-area C, gm dry weight totals, sites 1-5.

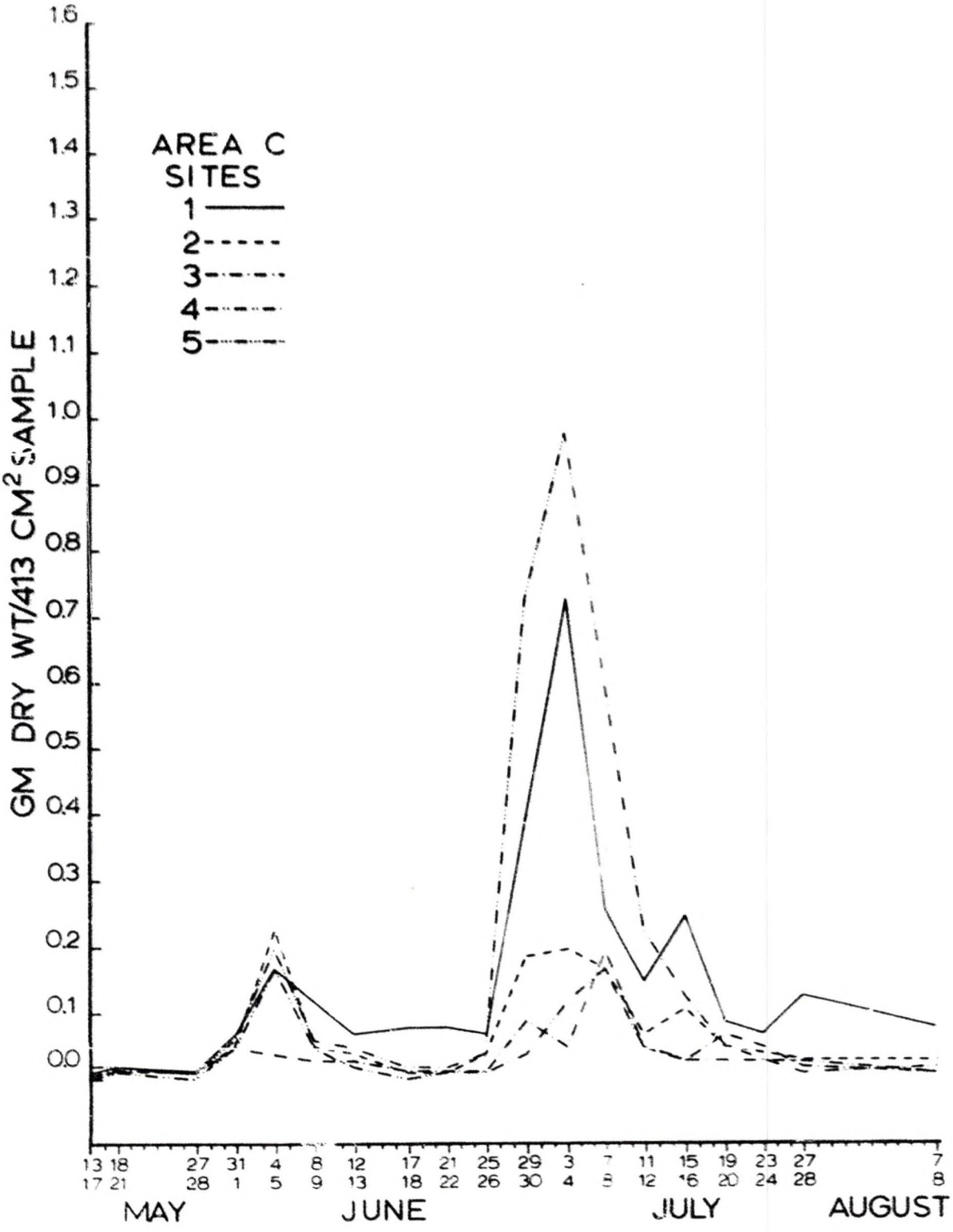

AREA C
SITES
1
2
3
4
5
GM DRY WT/413 CM² SAMPLE
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
13 18 27 31 4 8 12 17 21 25 29 3 7 11 15 19 23 27 7
17 21 28 1 5 9 13 18 22 26 30 4 8 12 16 20 24 28 8
MAY
JUNE
JULY
AUGUST

Figure 11. Sticky trap results-area D, gm dry weight totals, sites 1-5.

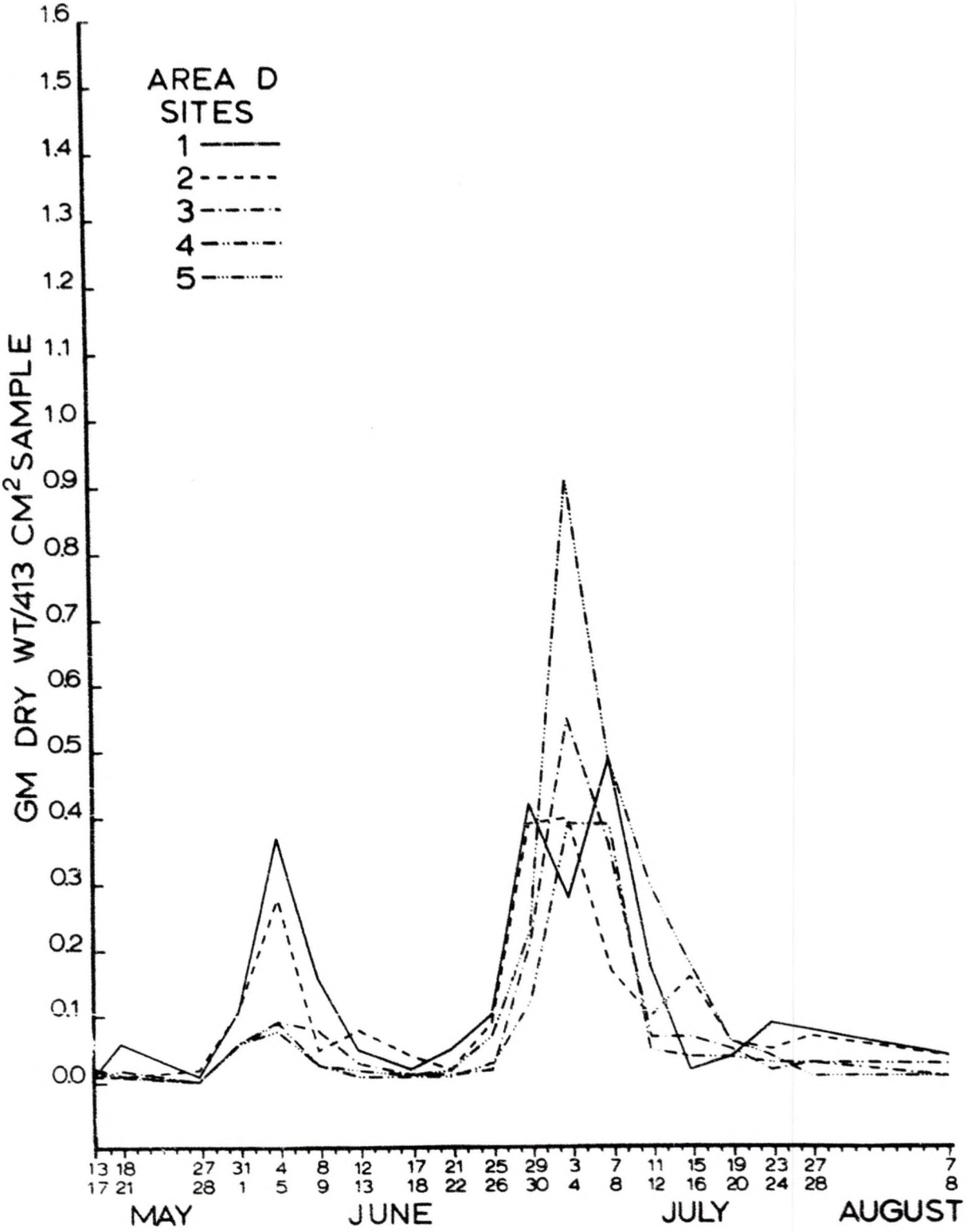

AREA D
SITES
1
2
3
4
5
GM DRY WT/413 CM² SAMPLE
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
13 18 27 31 4 8 12 17 21 25 29 3 7 11 15 19 23 27 7
17 21 28 1 5 9 13 18 22 26 30 4 8 12 16 20 24 28 8
MAY
JUNE
JULY
AUGUST

Figure 12. Sticky trap results-area E, gm dry weight totals, sites 1-5.

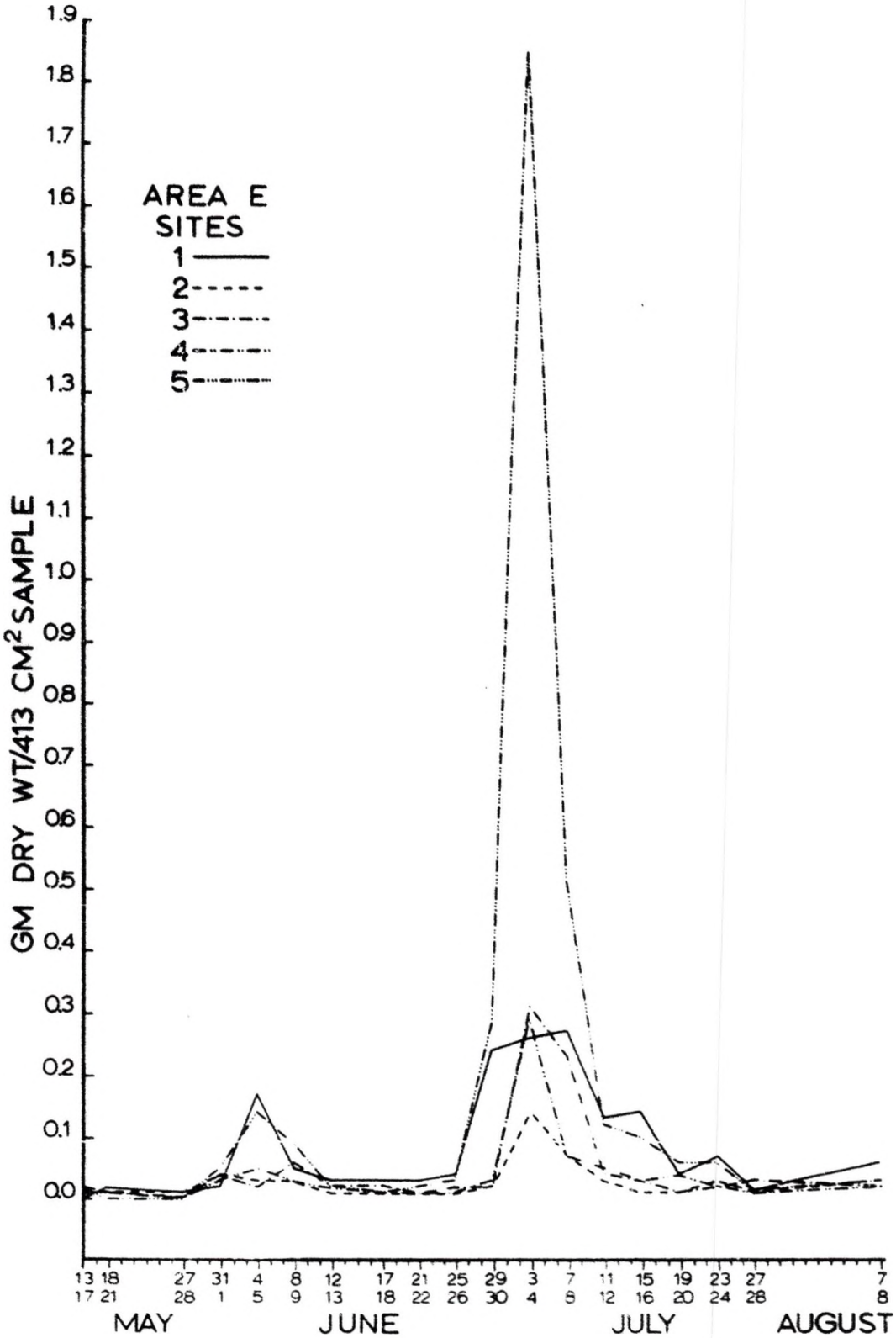

AREA E
SITES
1
2
3
4
5
GM DRY WT/413 CM² SAMPLE
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
13 18 27 31 4 8 12 17 21 25 29 3 7 11 15 19 23 27 7
17 21 28 1 5 9 13 18 22 26 30 4 8 12 16 20 24 28 8
MAY
JUNE
JULY
AUGUST

Figure 13. Gm dry weight totals, sites 1-5 of areas (A-E) combined.

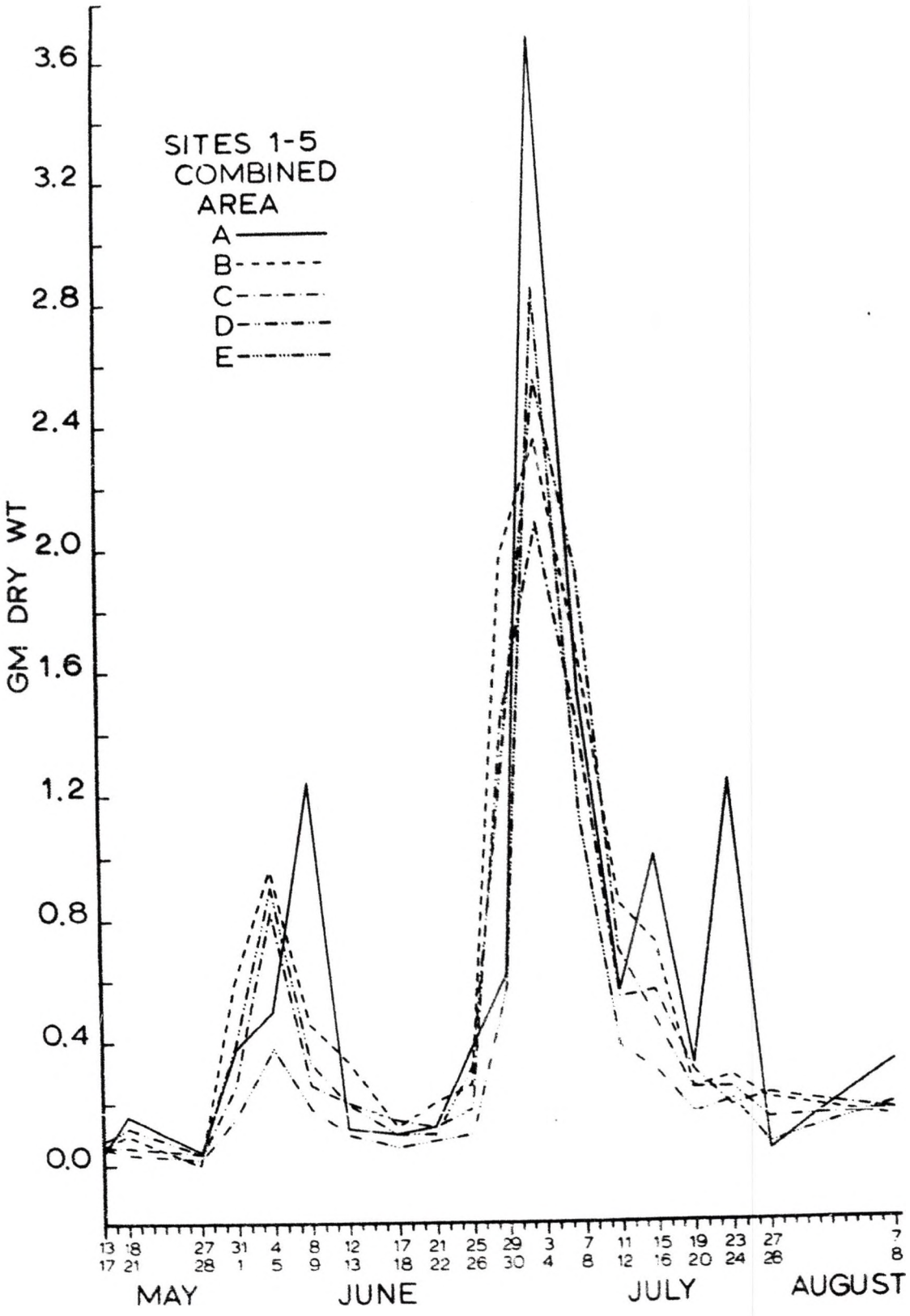
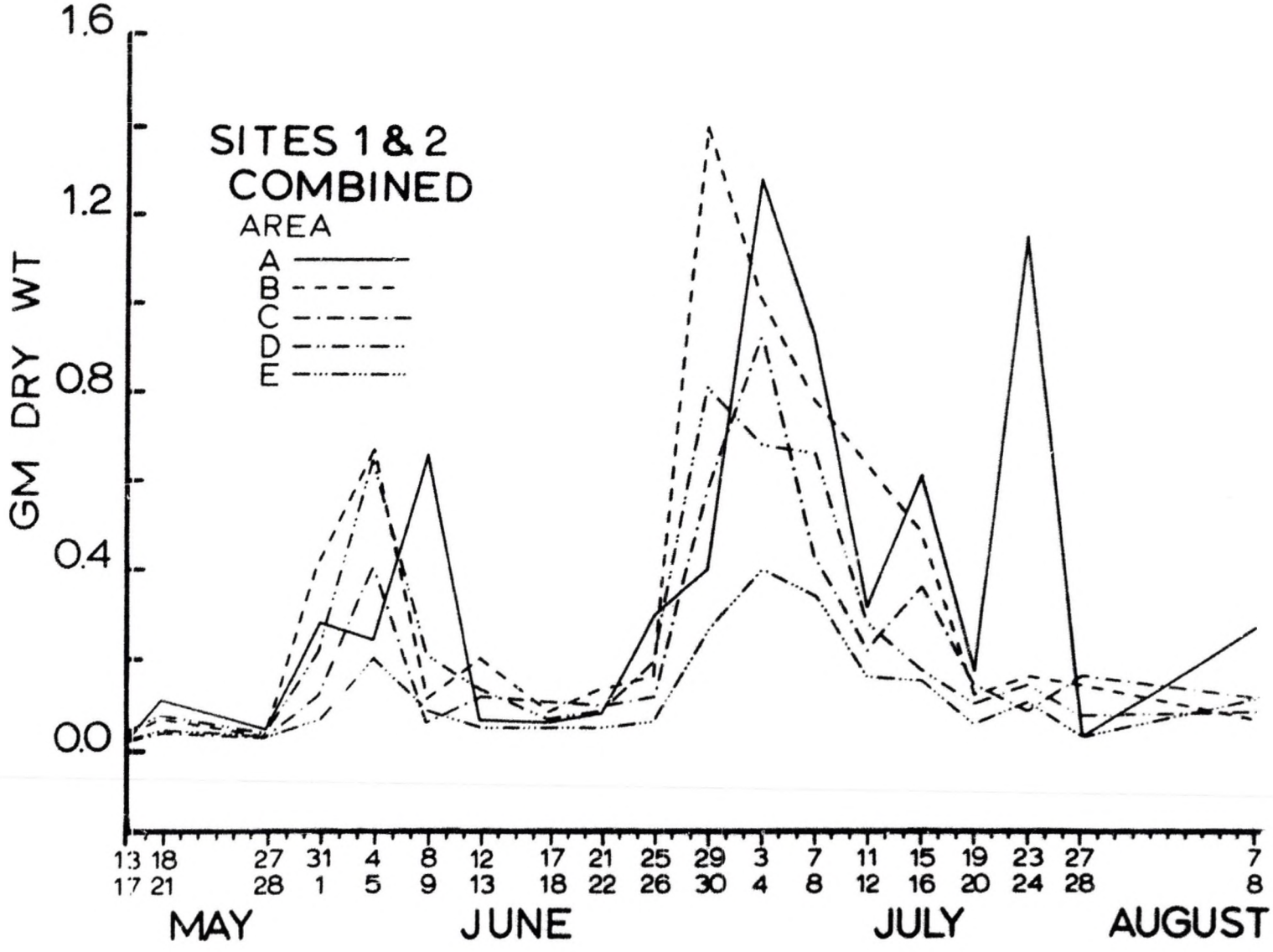

SITES 1-5
COMBINED
AREA
A
B
C
D
E
GM DRY WT
3.6
3.2
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
13 18 27 31 4 8 12 17 21 25 29 3 7 11 15 19 23 27 7
17 21 28 1 5 9 13 18 22 26 30 4 8 12 16 20 24 28 8
MAY
JUNE
JULY
AUGUST

Figure 14. Gm dry weight totals, sites 1 and 2 of areas (A-E) combined.


SITES 1 & 2
COMBINED
AREA
A
B
C
D
E
GM DRY WT
1.6
1.2
0.8
0.4
0.0
13 18 27 31 4 8 12 17 21 25 29 3 7 11 15 19 23 27 7
17 21 28 1 5 9 13 18 22 26 30 4 8 12 16 20 24 28 8
MAY
JUNE
JULY
AUGUST

that time. The third hatch took place during the last week of July. During that week, strong winds from the northwest (Fig. 6) forced most of the principal insects, caddisflies (Helicopsychidae), to the main beach on the southeast side of the island. This accounted for the large peak in the results of site 1, area A (Fig. 8).

Results of trap sites 1 and 2 combined illustrate wind induced variations in trap success (Fig. 14). Areas located on leeward or sheltered sides of the island exhibited higher success than those on exposed sides.

Three sticky traps were lost during the summer to wave action. Site 1 of area D on 28 July, and sites 1 of areas B and C on 8 June were washed away during high winds which caused extensive beach erosion.

A high degree of variability in trap success was evident, not only between sites, but also between areas (Fig. 8-14). To determine the magnitude and source of this variation, an analysis of variance was used which incorporated wind speed and direction as two of the variables. Resultant wind directions and velocities for each sample period were analyzed with sticky trap results in a Four Way Hierarchical Model with Disproportionate and Missing Cells (Searle, 1971; Williams, 1974).

Analysis I (Table 3) indicates that significant differences in trap catch which occurred, could be attributed to wind speed, different trap sites, and the interaction between wind speed and direction. Differences attributable to different wind directions or different areas were not significant.

TABLE 3

ANALYSIS OF VARIANCE OF THE INFLUENCE OF WIND DIRECTION, WIND SPEED, TRAP AREA, AND TRAP SITE ON STICKY TRAP DRY WEIGHT SAMPLES

	df	SS	MS	F[a]
Wind Speed (WS)	1	457945	457945	15.99[a]
Wind Direction (WD)	3	149888	49963	1.74
Area	4	230140	57535	2.01
Site	4	1068648	267162	9.33[a]
WS X WD	2	2366484	1183242	41.33[a]
Error	435	12461103	28646	

[a] $p < .01$.

Mean trap catches (gm dry wt) during winds of high and low velocities for four resultant directions are presented in Table 4. A value for northerly winds of low velocity was not obtained from calculations of resultant directions. This constitutes the missing cell. Means of trap catch during southerly winds of high velocity and westerly winds of low velocity were largest whereas the mean obtained during northerly winds of high velocity was smallest.

Means of trap catch for trap areas (A-E) and sites (1-5) indicate that areas A and B experienced highest catches whereas areas C and E exhibited lowest trap success (Table 5). Sites 1 and 5 experienced higher

TABLE 4

MEAN DRY WEIGHT (gm) STICKY TRAP CATCHES DURING HIGH AND LOW WINDS FROM VARIOUS DIRECTIONS

		Direction			
		E	W	N	S
Speed	H	1.20	.44	.24	1.59
	L	1.2[illegible]	3.07	--	.70

NOTE: Wind speed is considered low if less than 10 mph. A wind speed greater than or equal to 10 mph is considered high.

TABLE 5

MEAN DRY WEIGHT (gm) FOR STICKY TRAP SAMPLES FROM AREAS A-E AND SITES 1-5

		Area					
		A	B	C	D	E	Ave.
Site	1	3.06	2.59	1.54	1.40	.85	1.89
	2	1.05	1.23	.71	1.18	.27	.89
	3	.55	.82	.41	.94	.50	.64
	4	.99	.91	.46	.76	.39	.70
	5	1.36	1.05	1.82	1.40	1.87	1.50
Ave.		1.40	1.32	.99	1.14	.77	

trap success than sites 2, 3, or 4. Significant differences in trap success can be attributed to area variability and wind direction when wind speed and sites are dropped as variables (Table 6).

Mean values (gm dry wt) of areas (A-E) for winds of four resultant directions (Table 7) indicated winds of northerly direction were characterized by least trap success. Average catches for easterly, westerly, and southerly winds were comparable.

Shoreline Samples

Amphipods, cladocera, and copepods accounted for 79% (by number) of the organisms taken in shoreline samples (Table 8). Ephemeroptera and Diptera larvae and adults comprised 15% of the total. Shoreline areas II and III exhibited higher catches and less fluctuations in numbers than did other areas (Fig. 15-19). Larger organisms (>10 mm) were typically more abundant in shoreline area III (Fig. 17). Shoreline area V (Fig. 19) was the least productive.

Vegetational Densities

Relative vegetational densities, averaged for the five trap sites of each area, indicated that area E was characterized by the densest vegetation, 23-30% higher than areas A, C, and D (Table 9). Areas A, C, and D varied only 7% in relative density, each being 17-24% more dense than area B.

Vegetational densities of trap sites analyzed with sticky trap results for the last three sample periods of July indicated that trap catch

TABLE 6

ANALYSIS OF VARIANCE OF THE INFLUENCE OF WIND DIRECTION, AREA, AND WIND DIRECTION-AREA COMBINED ON STICKY TRAP DRY WEIGHT SAMPLES

	df	SS	MS	F
Area	4	387659	96915	2.54[a]
Direction	3	359841	119947	3.19[a]
Interaction	12	151577	12631	.34
Within	430	16144553	37545	
		16734375		

[a] $p < .05$.

TABLE 7

MEAN DRY WEIGHT (gm) STICKY TRAP CATCHES FOR AREAS A-E DURING WINDS OF FOUR RESULTANT DIRECTIONS

		N	E	W	S
	A	.24	1.24	1.78	1.25
	B	.40	1.40	1.18	1.58
Area	C	.24	1.08	.89	1.17
	D	.19	1.48	1.08	1.13
	E	.14	.83	1.00	.58
Ave.		.24	1.21	1.19	1.14

TABLE 8

PERCENTAGE CATCH OF PRINCIPAL GROUPS OF INVERTEBRATES CAUGHT IN SHORELINE SAMPLES

Group	Percentage of Total
Phylum Arthropoda	
Class Eucrustacea	
Subclass Branchiopoda	
Order Cladocera	32.27
Subclass Copepoda	11.52
Subclass Malacostraca	
Order Amphipoda	34.92
Class Insecta	
Order Diptera	
Larvae	5.64
Adults	4.55
Order Ephemeroptera	
Larvae	5.40
Adults	.22
Order Hemiptera	2.24
Phylum Annelida	
Class Oligochaeta	1.32
Class Hirundinea	.22

Figure 15. Shoreline sample area I-no of organisms per m^3 H_2O.

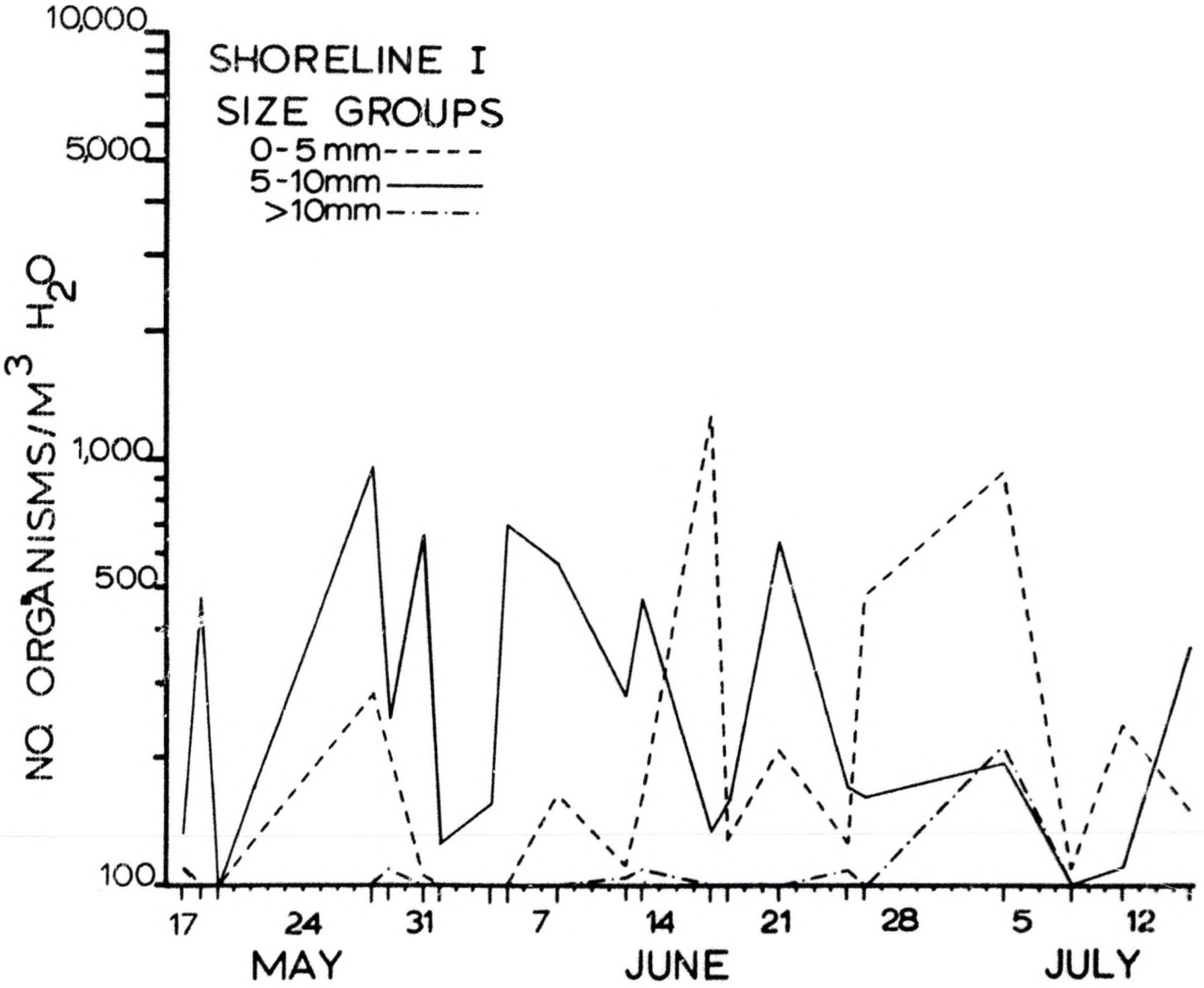

SHORELINE I
SIZE GROUPS
0-5 mm
5-10mm
>10mm
NO. ORGANISMS/M3 H2O
10,000
5,000
1,000
500
100
17
24
31
7
14
21
28
5
12
MAY
JUNE
JULY

Figure 16. Shoreline sample area II-no of organisms per m^3 H_2O.

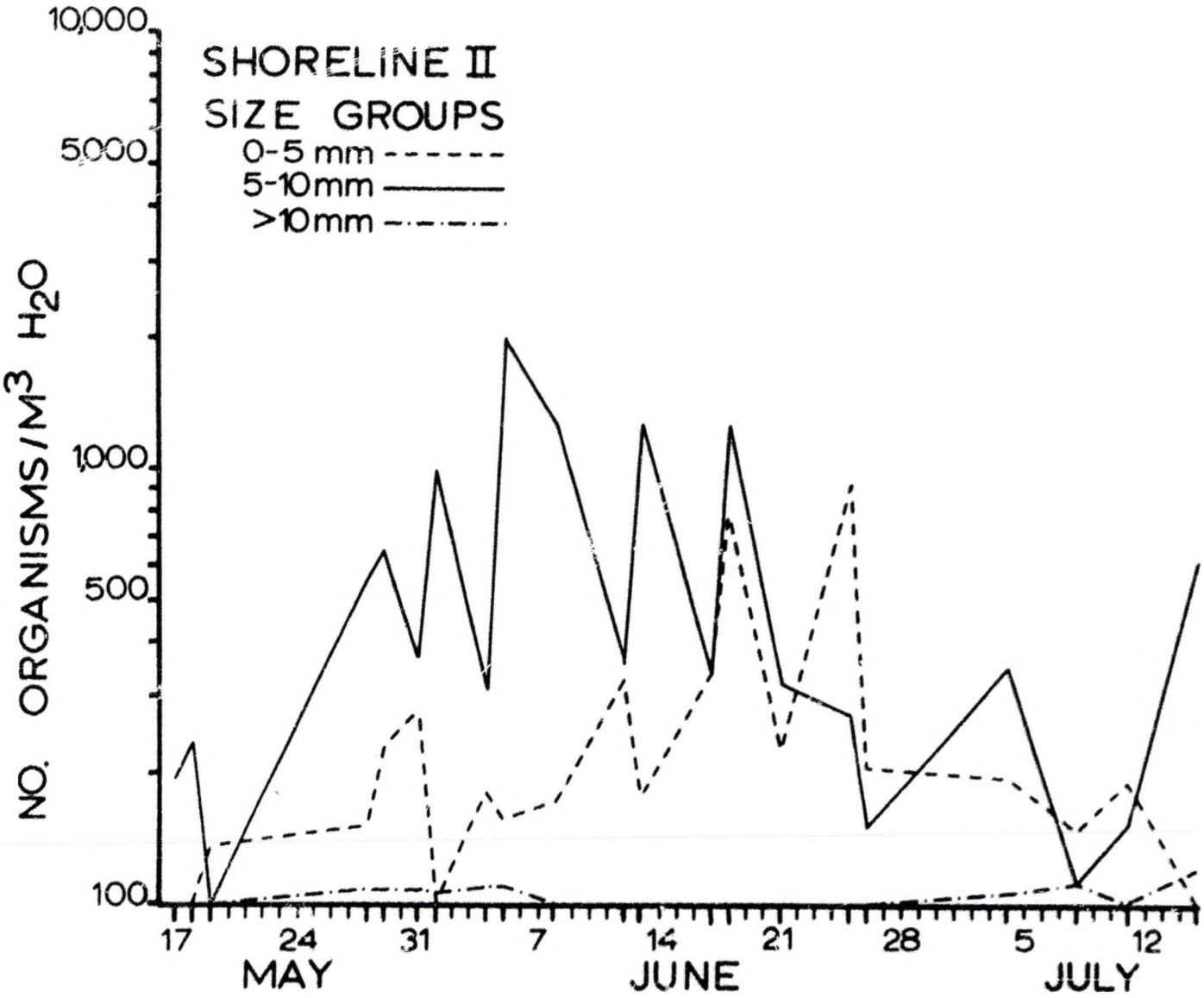

SHORELINE II
SIZE GROUPS
0-5 mm
5-10mm
>10mm
NO. ORGANISMS/M3 H2O
10,000
5,000
1,000
500
100
17
24
31
7
14
21
28
5
12
MAY
JUNE
JULY

Figure 17. Shoreline sample area III-no of organisms per m^3 H_2O.

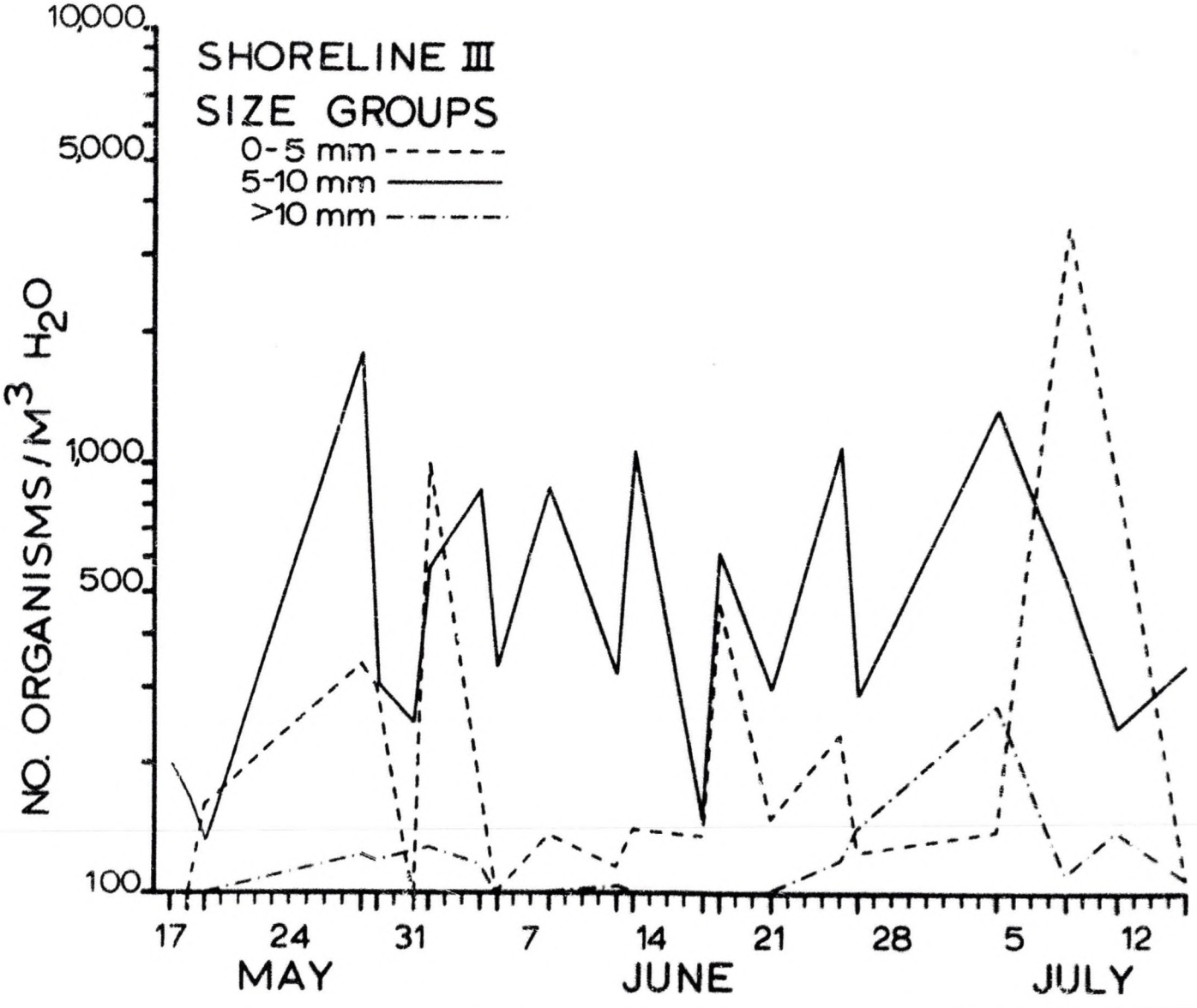

SHORELINE III
SIZE GROUPS
0-5 mm
5-10 mm
>10 mm
NO. ORGANISMS / M3 H2O
10,000
5,000
1,000
500
100
17
24
31
7
14
21
28
5
12
MAY
JUNE
JULY

Figure 18. Shoreline sample area IV-no of organisms per m^3 H_2O.

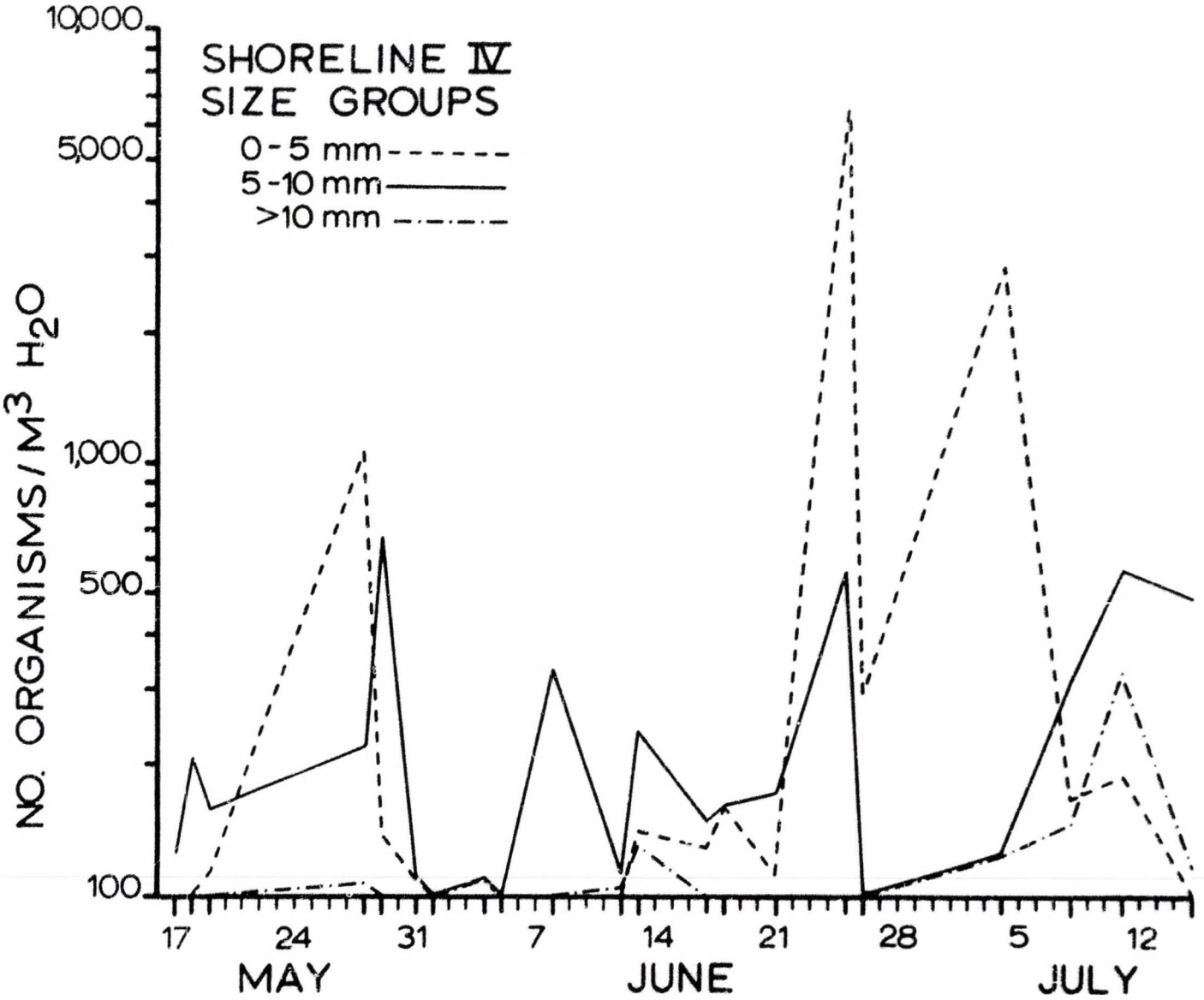

SHORELINE IV
SIZE GROUPS
0-5 mm
5-10 mm
>10 mm
NO. ORGANISMS / M3 H2O
10,000
5,000
1,000
500
100
17
24
31
7
14
21
28
5
12
MAY
JUNE
JULY

Figure 19. Shoreline sample area V-no of organisms per m^3 H_2O.

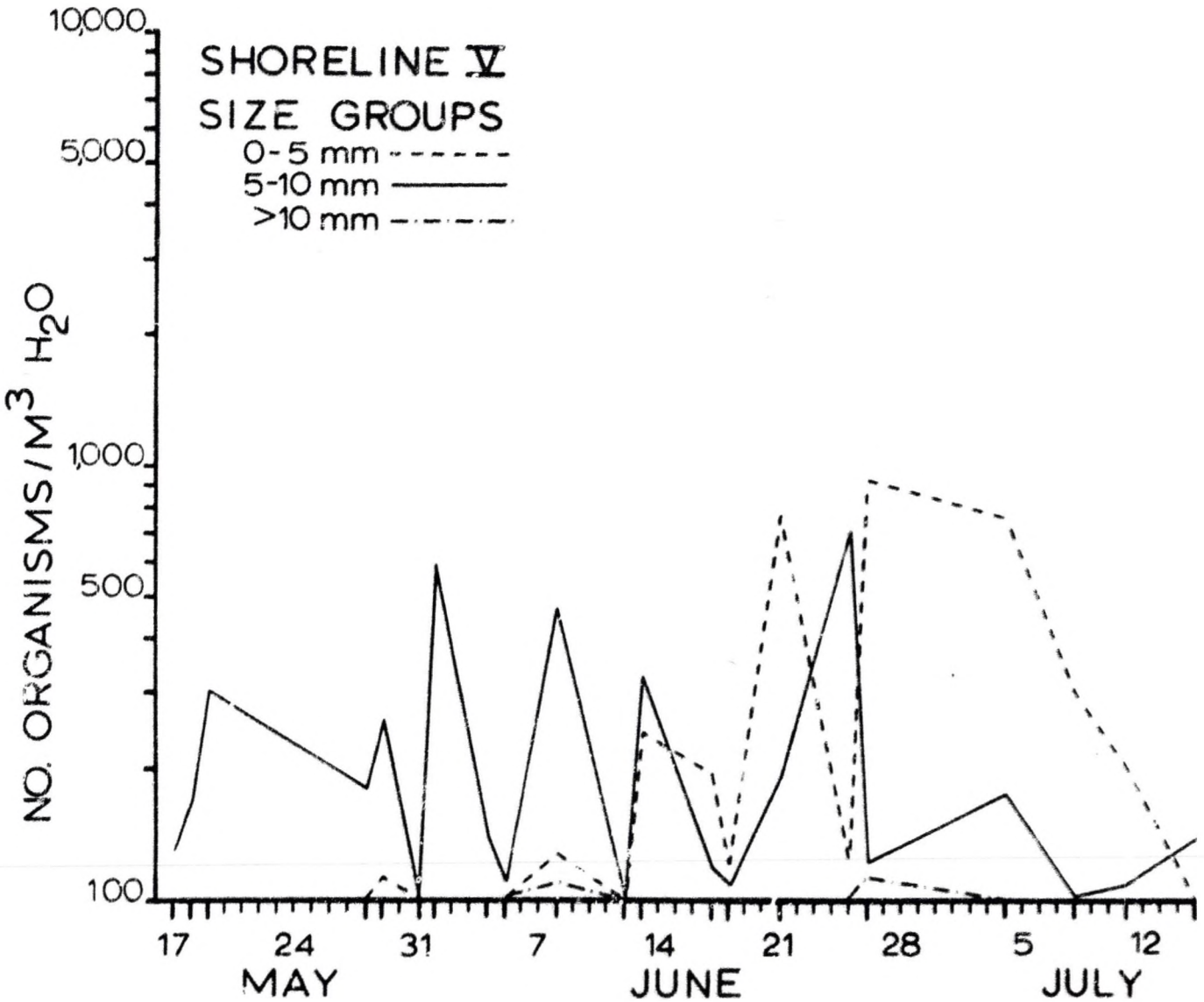

SHORELINE V
SIZE GROUPS
0-5 mm
5-10 mm
>10 mm
NO. ORGANISMS/M3 H2O
10,000
5,000
1,000
500
100
17
24
31
7
14
21
28
5
12
MAY
JUNE
JULY

TABLE 9

RELATIVE VEGETATIONAL DENSITIES FOR TRAP SITES INDIVIDUALLY, AND COMBINED BY AREA[a]

		A	B	C	D	E
	2	.1046	.4679	.4339	.3806	.7593
	3	.8927	.4624	.7385	.6483	.8567
Site	4	.7123	.5346	.5010	.7355	.8753
	5	.4793	.4605	.5213	.5344	.3469
Ave.		.5472	.4814	.5487	.5747	.7096

[a]Percentage of 1 m^2 backdrop covered.

was negatively correlated with vegetational density (Table 10). Strongest correlation can be seen for the sampling period 27 and 28 July ($r = -.61$), which includes the date when vegetational densities were determined.

TABLE 10

CORRELATIONS OF RELATIVE VEGETATIONAL DENSITIES TO CATCHES FOR THE LAST THREE SAMPLING PERIODS OF JULY

	r
Trap catch 1 (19 and 20 July)	$-.34^a$
Trap catch 2 (23 and 24 July)	$-.35^a$
Trap catch 3 (27 and 28 July)	$-.61^b$

NOTE: Vegetational densities were recorded on the 28th of July.

[a]$p < .05$.

[b]$p < .01$.

Feeding Observations

Birds responded to high levels of food from 1 to 5 June and 29 June to 12 July by decreasing the percentage of time spent feeding on open beach (Fig. 20-22). Male Galrt and female Balrt spent less total time on the beach from 29 June to 12 July (Fig. 20) whereas male RB/al and female BR/al spent a larger percentage of their time on the open beach but less time foraging (Fig. 21).

Overall averages of times spent on beach and percentage of time spent feeding indicated birds on the north beach (Area D) spent more time foraging on open beach habitat than did other birds on other beaches (Table 11). Birds on the northeast beach (Area B) spent more time on the open beach, but foraged there less than did birds on the north beach. Birds on the southeast beach (Area A) spent the least amount of time in open beach habitat and the least amount of time foraging there.

Peck rates recorded throughout the summer averaged for 13 birds on four beaches are presented in Figure 23. Rates averaged .5 pecks/sec for the summer. Overall rates appeared to vary little throughout the season with the exception of the period 21 June through 27 June when rates were markedly higher. During that period, birds on the north beach foraged at rates which were two to three times that observed during other periods of the summer.

Insects and aquatic organisms washed up on the beaches were important energy sources for foraging birds. As an example, one bird on the northeast corner of the island (RB/al) on the morning of 12 June, was

Figure 20. Percentage time feeding and total time on open beach- of male Galrt and female Balrt.

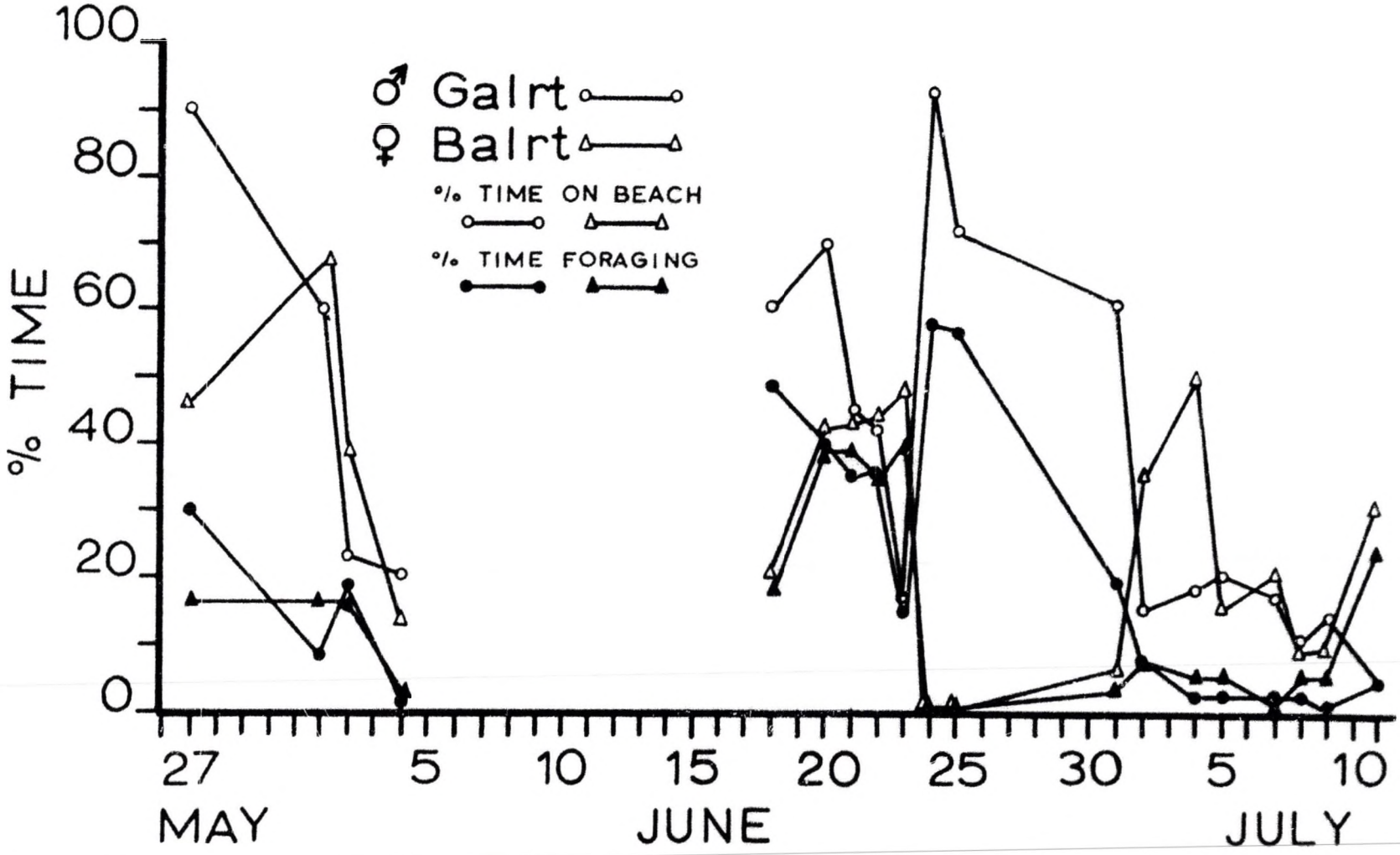

100
80
60
40
20
0
% TIME
♂ GaIrt
♀ BaIrt
% TIME ON BEACH
% TIME FORAGING
27
5
10
15
20
25
30
5
10
MAY
JUNE
JULY

Figure 21. Percentage time feeding and total time on open beach-
pair of male RB/al and female BR/al.

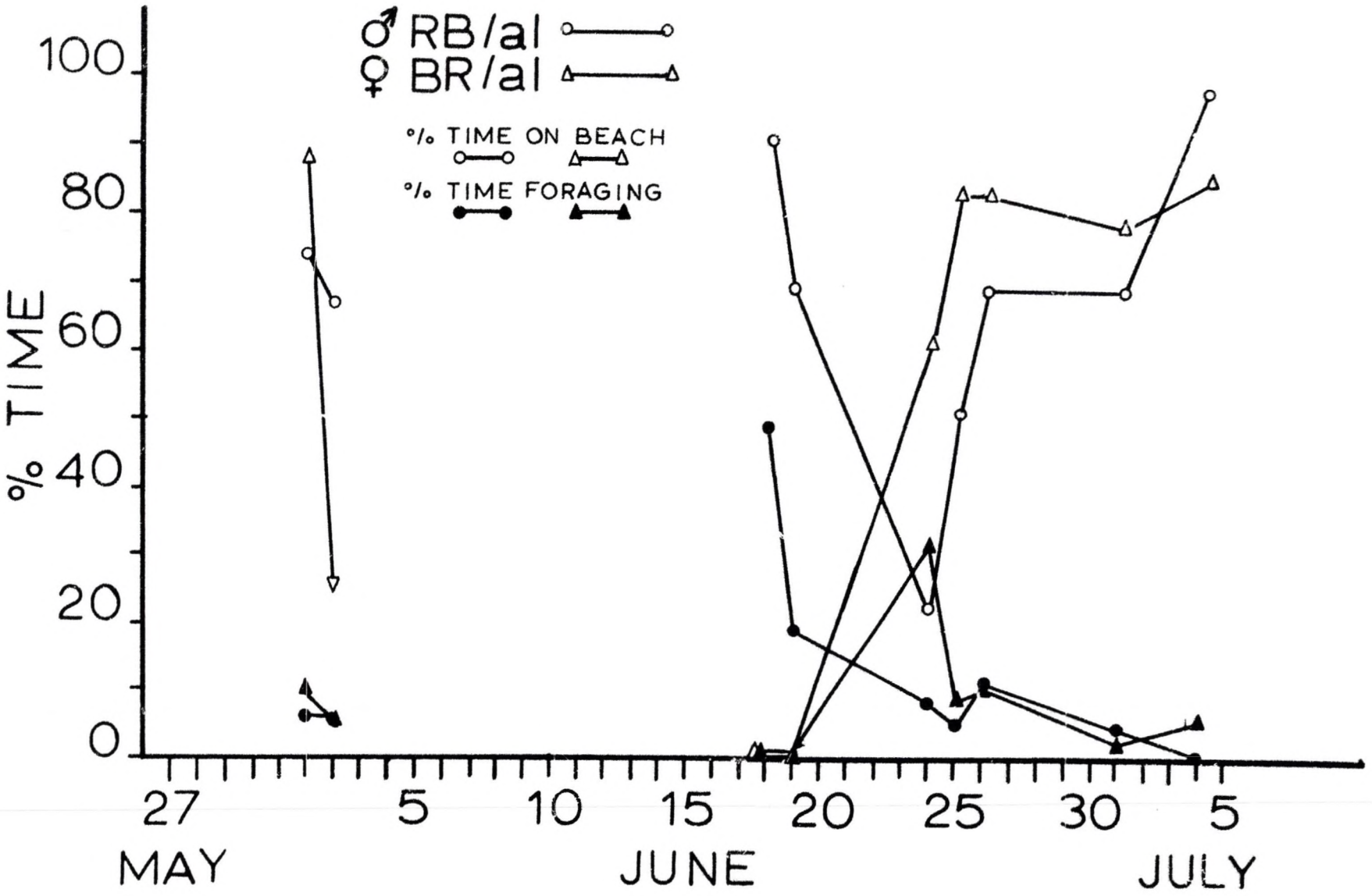

♂ RB/al
♀ BR/al
% TIME ON BEACH
% TIME FORAGING
% TIME
100
80
60
40
20
0
27
5
10
15
20
25
30
5
MAY
JUNE
JULY

Figure 22. Beach averages-percentage of time on beach and time spent foraging.

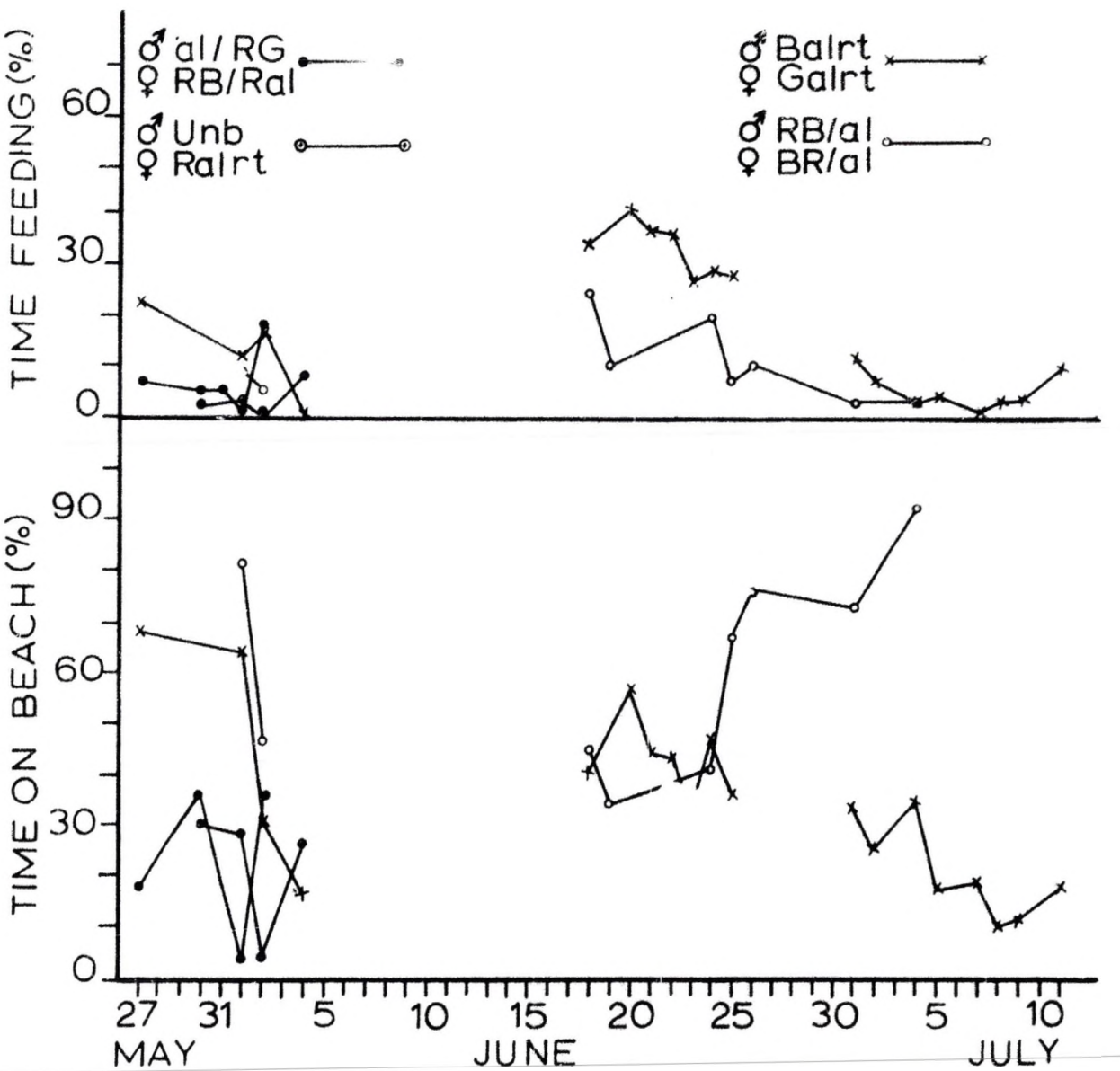

♂ al / RG
♀ RB/Ral
♂ Unb
♀ Ralrt
♂ Balrt
♀ Galrt
♂ RB/al
♀ BR/al
TIME FEEDING (%)
60
30
0
TIME ON BEACH (%)
90
60
30
0
27
31
5
10
15
20
25
30
5
10
MAY
JUNE
JULY

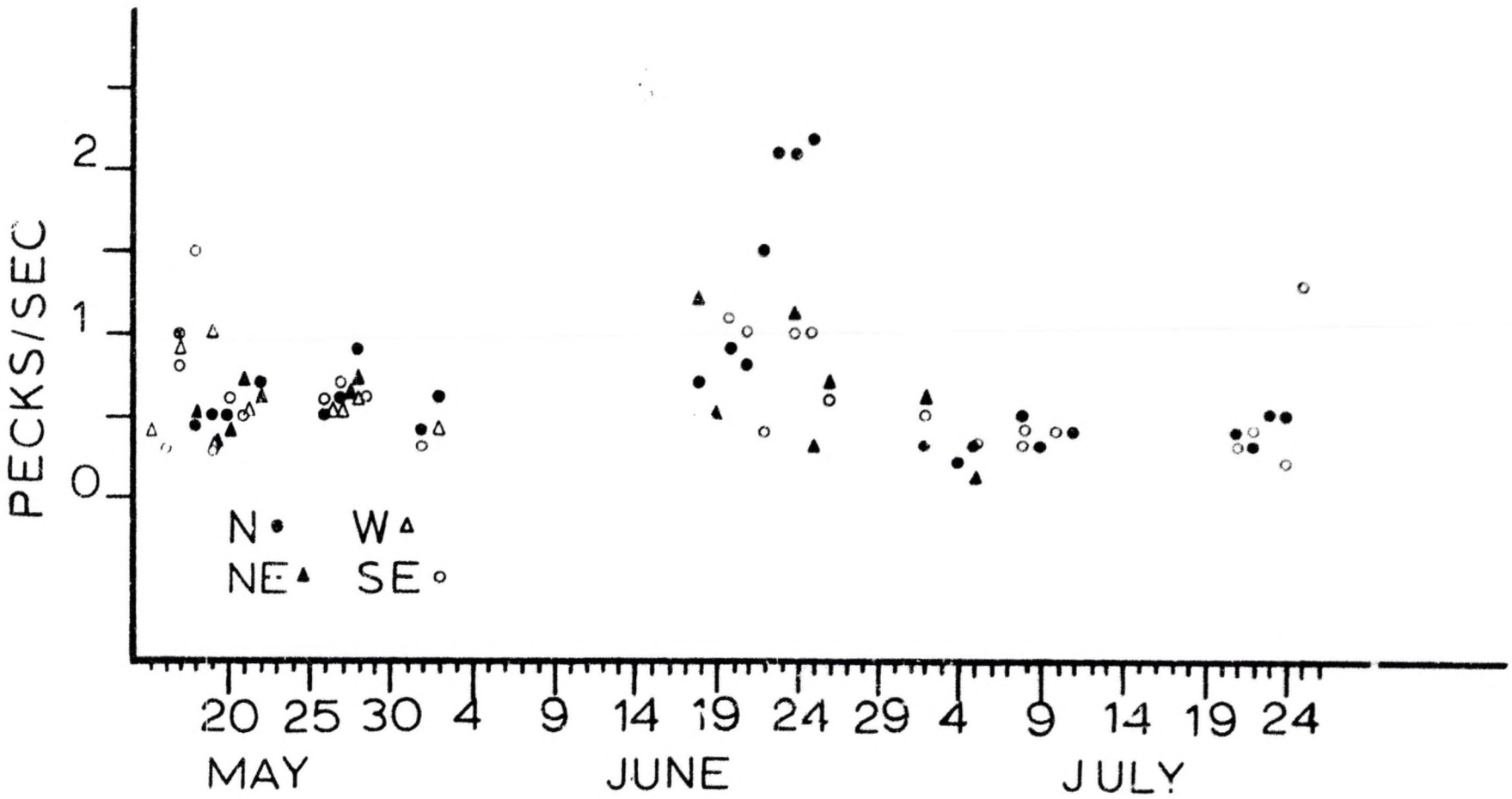
TABLE 11

PERCENTAGE TIME SPENT ON OPEN BEACH VERSUS PERCENTAGE TIME SPENT FORAGING FOR BIRDS ON THREE BEACHES

	Beach		
	N	NE	SE
Total time on beach (percentage of each hour)	.34	.70	.25
Total time spent foraging (percentage of each hour)	.17	.12	.07
Number of birds	3	3	5

seen concentrating its feeding along a limited stretch of beach, exhibiting peck rates which averaged 1.4 pecks/sec. Close examination of the sand revealed large numbers of amphipods (39 in a 1 m stretch of beach) on the wet sand. During the period shortly after the peak mayfly hatch, large numbers of imagos were spread along the beaches in drift lines. These provided a convenient source of food for the birds, as mayflies and chironomids not eaten by birds were soon full of dipteran larvae. Birds probed and stitched (Burton, 1974; also referred to as jabbing by Holmes, 1966) while feeding on the larvae. These feeding movements were not seen to any great extent during other parts of the season and indicated a definite change in feeding strategy resulting from utilization of a different food item. On 13 July, several birds were observed using these feeding styles along the southeast beach.

Figure 23. Peck rates averaged for thirteen birds of four beaches.


PECKS/SEC
0
1
2
N • W △
NE ▲ SE ○
20 25 30 4 9 14 19 24 29 4 9 14 19 24
MAY
JUNE
JULY

Individual birds maintained a remarkable degree of plasticity, exhibiting bouts of high and low specificity. For example, on 9 June food items were abundant on the southeast beach (Fig. 13). A female (al/BW) was observed feeding alternately along the water edge, beach drift line, and vegetation fringing the beach. Peck rates averaged 1.25 pecks/sec for five minutes of continuous feeding. The bird appeared to be eating any and all food items it came across including many small diptera and aquatic organisms. Two hours later the bird was observed basking in the sun. Every few minutes, it interrupted its sunning to stalk large Diptera (Muscidae and Anthomyidae) that were active on the beach. In two minutes, it attempted to capture 22 flies and was successful 14 times. Several minutes later, the bird disappeared into the vegetation, eating small dipterans and again showing a high peck rate.

At times when insect abundance was low, for example 26 to 28 May (Fig. 13), feeding selectivity decreased and a great variety of food items were taken. One male (YR/al) was observed foraging on the north beach on the 27th. In a two-minute period, the bird completely submerged itself three times to reach a number of dead minnows along the beach. After three dives and three minnows, the bird moved into the brush. Another bird, a female (Balrt) observed during the same period along the same beach attempted to eat a large leech (approx. 15 cm) that had washed up near the shore. After four unsuccessful attempts, each preceded by washing the prey, the bird abandoned the effort and moved out of sight. On the 28th, another male (G/Yal) tried unsuccessfully to

swallow a dead crayfish that had washed up on the beach.

Three females, especially Bairt on the north beach, were observed during the first week of July exhibiting what appeared to be preferential feeding behavior. All three were observed in prolonged feeding bouts along the water edge, virtually ignoring large numbers of mayflies and chironomids. Their peck rates were high, 1.5 to 1.7 pecks/sec, indicating that small items were being taken. However, close examination of the substrate revealed nothing that could be considered food. Agitation of the top layer of moist sand in a jar with water revealed that a number of small copepods and cladocera were present (all less than 3 mm size). Whether the birds utilize a food source that small remains to be seen when stomach contents are available. Holmes (1966) found that redbacked sandpipers (Calidris alpina) do not utilize food items smaller than 3 mm in the case of flying insects and less than 5 mm in the case of chironomid larvae. It appears that the spotted sandpipers are ingesting something at least that small.

On several occasions, a number of birds were observed flying to the nearby tern island. After a few minutes the birds returned. From 13 to 21 June, I recorded six such instances. A trip there revealed that small diptera (family Ephydridae), were abundant although not at levels one would expect to warrant flights to and from the island. Large amounts of tern droppings and discarded remains of fish apparently provided a productive substrate for the flies. Whether the birds were feeding on flies or fish is unknown. Similar instances of birds taking advantage of localized

concentrations of food items have been reported by Williams (1958), Howell and Bartholomew (1954) and Horn (1968).

DISCUSSION

Terrestrial Arthropod Distribution

Statistical analysis of gm dry weight totals of sticky trap catches indicated that wind speed was a dominant factor influencing the distribution of terrestrial arthropods (Table 4). Velocities of 10 mph or higher reduced trap success significantly. Reduction of trap success, although a possible result of reduced insect activity, was more likely due to wind induced mortality. The majority of insects available on the island were midges and sciarids (Chironomidae and Sciaridae, Table 2), both of which are weak flyers. When wind velocity was high for extended periods of time, it appears likely that many were blown off the island.

When wind speed and direction were analyzed together, significant differences in insect catch due to area or direction alone were not evident (Table 3). A second analysis excluding wind speed as a variable (Table 6) indicated that some of the differences in trap success could be attributed to qualitative differences between areas and changes in wind direction. Failure to obtain significant levels for area and direction in the first analysis are due to the design of the hierarchical analysis. The appearance of significant levels for these two factors in the second analysis indicates that trap catch was influenced to some degree by differences of areas and changes in wind direction. However, the total contribution

of these two factors to variance is negligible compared to that contributed by wind speed.

Means of trap catch (gm dry weight) for resultant wind directions at low and high velocities indicated that trap success was highest during west or south winds at high or low velocities respectively (Table 4). Higher trap success could have been due to a number of factors including: 1) The influence of vegetation on insect distribution--the vegetational makeup of the island was such that more insects came in contact with traps when wind was from the west at high velocities or from the south at low velocities. 2) The position of lake hatching sites relative to the island--hatching sites may have been just south or west of the island. 3) The nature of winds at times of peak hatches--the timing of localized hatches may have coincided by chance with certain wind directions and velocities. Wind readings taken during peak hatches were primarily southerly or westerly which supports the third alternative.

Inter-Area Variation

Wind induced variations in trap success from one area to another were especially evident (Fig. 13 and 14). For example, on 4 and 5 June the wind blew strongly from the south and southwest (Fig. 6). During the sampling period of 8 and 9 June, wind was from the west and northwest. The low value for area A on the 4th and 5th, and the subsequent rise in trap success during the 8th and 9th were undoubtedly due to wind. Another example can be seen for 29-30 June through 3-4 July (Fig. 13). Areas A and E showed lower trap success on the former date due to the

influence of southeasterly and southwesterly winds (Fig. 6). When northwesterly winds were experienced during the latter period, trap success of areas A and E increased beyond that of other areas.

Examination of area means for four resultant wind directions (Table 7) indicated that trap success typically was higher when areas were sheltered from wind. All areas with the exception of area E exhibited highest success when wind was from the opposite side of the island or from a direction in which vegetation afforded maximum protection. The departure of data from area E from this pattern is easily explained. During the first three days of July resultant wind direction was westerly (averaged readings from Fig. 6). Site five of area E accumulated a huge number of mayflies (Fig. 12) which greatly influenced the mean value for westerly winds. Site 5 was sheltered in dense vegetation near the island interior where large numbers of mayflies accumulated in the interim between mating flights. Subsequently, site 5 experienced a large catch regardless of wind direction.

Mean trap success was lower for all areas during northerly winds (Table 7). The overall dry weight mean for samples collected during northerly winds was about 20% of dry weight means for collections made during winds of other directions. Lower values obtained for northerly winds appeared to be the result of two principal factors: 1) Wind was rarely northerly during peak hatches (Fig. 6 and 11) and as a result, the overall mean would be lower than those for winds that occurred frequently during the hatches. 2) Failure to obtain a resultant value for northerly

winds of low velocity (Table 7) results in a missing cell which is passed over in the statistical analysis under the assumption that no trap catch was obtained during north winds of low velocity. In view of the fact that winds of high velocity resulted in reduced catch (Table 4), the true value of the mean should be higher.

Other factors which could have contributed to the lower mean for northerly winds were temperature and precipitation levels for days on which northerly winds occurred. Precipitation records (Fig. 7) and average daily temperatures (Fig. 5) showed that days on which the wind blew from the north were not wetter and only slightly colder (1° C) than days on which the wind blew from other directions. However, continuous temperature readings were not available for the period of 15 through 30 July. This seemed to be a time when temperature variations were strongly correlated with wind direction. During this period northerly winds were in fact considerably colder than for example, southerly winds.

Wind data for the summer of 1974 indicated that northwesterly and westerly winds were typically of higher velocities and longer durations than winds from other directions. As an example, the northwesterly winds during 25-30 July averaged 15 mph velocity and blew for a total of at least 90 of 120 possible hours during that five-day period. Since northwest winds were fairly frequent throughout the summer (Fig. 6), the high velocities associated with them may have been a contributory factor to the low mean for northerly winds.

Inter-Site Variation

Differences in trap catch (gm dry weight) between sites were significant (Table 3), undoubtedly d ıe to inter-site differences in vegetation density. Vegetation densities at trap sites were correlated with trap catch (Table 9)--as vegetation increased, trap success diminished. Habitat preferences of insect groups, though present to some degree (e.g., Trichoptera on open beaches), were not a major factor contributing to the significance.

Seasonal gm dry weight means for trap sites (Table 5) indicated that the much larger catches of sites 1 and 5 were the source of significance. Sites 1 and 5 were by far the most productive, with the exception of area B where site 2 showed a slightly higher catch than that for site 5.

Open beaches, where site 1 was located, typically had a great deal of insect activity and experienced substantial success when sheltered (Fig. 8-12). High trap success was due to numerous small mating flights (primarily Sciaridae and Chironomidae) which occurred along vegetation fringing open beaches. Air turbulence occasionally lifted whole mating flights and subjected them to wind induced impaction on open beach traps. Caddisflies, when present on the island, concentrated on open beaches and came in contact there with traps.

High catches in site 5 of each area should not be taken as evidence of an abundant supply of food items present throughout the summer. Rather, high means were the result of substantial mayfly catches experienced during the first week of July. During the remainder of the summer,

trap success for these areas was comparatively low (Fig. 8-12).

Areas with Greatest Insect Abundance

Area A had the largest expanse of open beach. Open beach in this area extended approximately 5 m from the water edge and at least 100 m the length of the main beach. This supplied the birds with at least 500 m^2 of productive foraging space. Since birds did not spend a great deal of time foraging on the beach on this side of the island (Fig. 22 and Table II) indications are that densities of food items throughout the semi-open beach habitat were more than adequate to meet energy requirements.

Area B characteristically showed a high trap success regardless of wind direction (Table 7). This was the result of its vegetational characteristics. Woody vegetation and dense undergrowth provided maximum shelter from winds of all directions except east. Wind permeability of the vegetation adjoining area B was low and probably was the underlying factor contributing to higher insect catches.

Lewis and Stephenson (1966) illustrated how insects accumulate in areas of maximum shelter and noted that large insects and swarmers are typically the ones that accumulate most, reaching densities 200 times that in unsheltered air. The most abundant insects on the island were sciarids and midges (Sciaridae and Chironomidae), both swarmers. Mayflies on the island (Heptageniidae and Ephemeridae), although large, are weak flyers and can be classified as swarmers.

Lewis and Dibley (1970) presented a graphic model illustrating shelter profiles provided by semipermeable barriers of varying density. When data are available on height and density of vegetation throughout the island, this, in conjunction with continuous wind records, should provide the means by which day to day and seasonal variations in the distribution of food items can be predicted.

Aquatic Invertebrate Distribution

Wind was also a dominant factor determining distribution and abundance of aquatic organisms. Windward sides of the island had fewer food items than sides sheltered from wave action (Fig. 15-19). Shorelines I and II (Fig. 15 and 16) on 19 May, and shorelines IV and V (Fig. 18 and 19) on 31 May and 4, 5, and 12 June all exhibited a reduction in the availability of aquatic organisms as a result of wave action. Organisms present along windward shores were fragmented, buried by sand deposition, or pushed around the island to more protected stretches of beach.

On several occasions, as much as five meters of new beach was formed by wave action. During beach formation, temporary sand-spit pools formed which were rich in aquatic invertebrates. One sample, taken from such a pool showed a density of amphipods and cladocera (Cladocera and Amphipoda-Class Eucrustacea, Table 8) at least 30 times that found along the beach. Birds foraged heavily in these temporary pools, especially along the main beach of area A where the majority of pools formed.

Waves followed the shoreline around to sheltered sides of the island, transporting large numbers of aquatic organisms into calmer

waters. The gently lapping effect of dissipated waves on protected shorelines resulted in the deposition of many aquatic organisms and dead insects into well defined drift lines. Birds concentrated their feeding along these lines, especially during early morning hours, ingesting dead imagos from mating flights of the preceding night along with amphipods, cladocera, and copepods.

Foraging Behavior

Cases of intersexual variation in bird foraging strategies have been well documented (Kilham, 1965; Selander, 1966; Williamson, 1971). Since energy demands interact with other factors in determining foraging behavior, one would expect female sandpipers--with great calcium and caloric needs imposed by their very large eggs--to have foraging strategies different from males. Recently MacLean (1974) found that breeding female red-backed sandpipers ingested lemming bones to a far greater degree than did males. His information strongly indicated that calcium from these bones was the principal source of egg calcium.

In a polyandrous species such as the spotted sandpiper, where an individual female may lay as many as 14 eggs in 28 days (Oring, Pers. Comm.), calcium and energetic demands are far greater yet than those of monogamous sandpipers studied by MacLean (1974). Whether or not female spotted sandpipers are selectively taking shelled organisms, fish scales, bones, or other calcium-rich objects remains to be documented through stomach analysis.

Baker and Baker (1973) devised a system for studying foraging behavior which incorporated locomotion pattern and frequency of feeding movement. Application of this system to spotted sandpipers, in an attempt to document intraspecific differences in foraging behavior, proved fruitless because: 1) Probing, one of the major categories, occurred on Little Pelican Island only during a very brief time when fly larvae were abundant amidst rotting mayflies, and 2) Very rapid feeding rates and highly variable locomotion patterns made it extremely difficult to quantify patterns.

Differential foraging between males and females was not apparent when time spent on open beach vs time spent feeding (Fig. 20 and 21) or when peck rates were compared. However, one or two hours per day may not be adequate to reveal inter-individual or inter-sexual variations, even when they exist. Time spent foraging on the open beach vs total time on the beach may not be an actual indication of total time spent feeding.

Time spent on the beach may be, in large part, a measure of foraging space available. The north and northeast beaches had relatively little semi-open beach habitat. Birds in these areas spent more time on the open beach (Table 11). Birds on the southeast beach where semi-open beach habitat was extensive, spent the least amount of time on the open beach. Percentages of time spent foraging on open beaches may be related to food levels since birds on the southeast and northeast beaches, where food levels were highest (Table 5), spent the least amount of time foraging on open beach (Table 11). Sufficient data were not available for

comparison of birds on the west beach to those elsewhere. During the peak hatch (1 to 7 July) there was a marked reduction in time spent foraging on all beaches (Fig. 20-22). This undoubtedly was the result of the large numbers of available mayflies. The large size of the insects enabled the birds to maximize their energy intake during relatively short feeding bouts.

Differences in peck rates between beaches were not significant (Fig. 23). Rates did not vary substantially during the summer except for the period 19 through 25 June. Peck rates were higher typically during that time due to greatly decreased insect availability (Fig. 8-13) caused by rainy weather (Fig. 7). Higher foraging rates are usually indicative of less selective feeding (Emlen, 1966; MacArthur and Pianka, 1966).

Theoretical models of foraging behavior predict that as food availability increases, animals feed more selectively (Emlen, 1966; MacArthur and Pianka, 1966; Schoener, 1969). Baker and Baker (1973) found that species foraging by pecking made fewer feeding attempts per unit distance during the summer and attributed this to selective foraging. Royama (1966, 1970) found that great tits (Parus major) were more selective at times of high food availability. Spotted sandpipers too appear to be more selective at times of high food availability sometimes concentrating on a single type of insect. This type of feeding behavior, involving deliberate stalking of a particular prey type was also observed for spotted sandpipers by Keunzel and Weigert (1973).

Theories for foraging optimization also predict that during periods of low food availability, decreased selectivity results. When food was scarce, peck rates went up and birds showed a high level of opportunism, feeding on such items as leeches, minnows, and dead crayfish--all items not normally consumed.

Interrelationships Between Food, Vegetation, and Sandpipers

The energetic costs of breeding are high, necessitating higher feeding efficiencies (Wolf and Hainsworth, 1972) and/or a more productive environment (Pennycuick and Bartholomew, 1973) than is necessary for body maintenance alone. Birds congregate in areas of high prey densities because of increased feeding efficiency (Goss-Custard, 1970). Since food availability is enhanced in areas protected from wind, one would expect that these areas would be heavily competed for, especially if suitable nesting cover is nearby.

Holmes and Pitelka (1968) stress the importance of adult insect prey as the primary source of food for shorebird chicks during the first two weeks of life. Spotted sandpiper chicks rarely venture onto the beach but rather are dependent upon adult insects in the territories of their parents. Densities of birds are higher and territories smaller on the southeast side of the island (Oring and Knudson, 1972). During late June and early July, birds with broods on the southeast beach should have a considerable competitive edge over birds nesting elsewhere, for it was here that greater insect trap success occurred--especially in July

(Fig. 13, Table 5).

At least 10 of 16 nests located on the southeast beach in 1974 were near linear ridges (Fig. 4). Areas between these ridges are unique in affording wind protection and hence having high insect populations while, at the same time, having low vegetational density. The light to moderate vegetational density of these ridges (e.g., site 2, area A, Table 9) is important from the standpoint of chick mortality. Dense vegetation not only inhibits chick foraging, but may also cause mortality in that chicks cannot tolerate dew-laden plants. Relative humidity on the island reached 100% nightly and dense vegetation remained wet much of the morning.

An important relationship existed between timing of insect hatches and nest initiation dates. Thirteen of 14 females initiated nests in a six day period from 29 May to 5 June (Oring, Pers. Comm.) immediately following the first large hatch of insects on the island (Fig. 12). With a five day period allowed for clutch completion and a 21 day incubation period, an interval of 26 days existed between onset of laying and hatching of chicks. The interval between the first and second hatches was roughly 26 days which means that chicks should have hatched just prior to the largest insect hatch. Timing of the two hatches was spaced so that adult sandpipers were able to utilize the abundant available energy sources during the first hatch for egg production while chicks should have benefited from the second hatch.

The laying of eggs correlated with peaks in food abundance has been reported (Gibb, 1950; Kluijver, 1951). More recently, Nettleship (1973) found that 46% of first eggs were layed within a span of three days and that 8 of 13 nests were completed within a three day period--the possible result of a sudden increase in availability of energy sources. Furthermore, Perrins (1965) found that there was an advantage in early nesting but great tits could not lay until energy levels were high enough to support egg production. Breeding spotted sandpipers on Little Pelican Island are probably dependent on the first hatch of the summer for energy needed in egg production.

Lack (1954) hypothesized that hatching is synchronized with periods of optimal food availability for chicks. Recent studies of Holmes (1970) and Nettleship (1973, 1974) support this. Data on insect hatches for the summer of 1975 (Steve Maxson, Pers. Comm.) indicate that the first hatch of that summer was one week later (than 1974) while the second major hatch occurred at the same time. Diapause in aquatic nymphs and larvae is usually terminated by photoperiod with water temperatures influencing the rate of development thereafter (Beck, 1968). Given any degree of similarity in water temperatures from year to year, length of developmental periods should vary little and hatches should occur at approximately the same times each year. The occurrence of the first hatch of 1975 one week later than 1974 was probably due to the very late spring of that year.

Timing of laying and hatching are two crucial aspects of a bird's reproductive strategy. In a polyandrous species, one would expect that early nest initiation would be advantageous from the standpoint of allowing more time for new clutches. On Little Pelican Island, aquatic organisms were abundant earlier than were adult insects. Territories which were best for this early, aquatic food were not the same as those ideal for adult insects at the time of chick growth. It is clear that nutrition-related advantages of some territories are different from those of others. During future summers, it will be interesting to see which territories naive birds compete most vigorously for, whether initiation dates vary consistently for different territories, and, if they do, are they most closely correlated with first appearance of sufficient energy levels for egg production, or alternatively, timed so that hatching chicks accrue maximum benefit from the large, second insect hatch.

SUMMARY

Insect sticky traps and shoreline samples were used from 12 May to 1 August, 1974 to determine the relative abundance and distribution of spotted sandpiper potential food items. Five terrestrial sample areas and five shoreline sample areas were picked which represented five different exposure angles on Little Pelican Island, Leech Lake, Cass Co., Minnesota.

Three major insect hatches occurred during the summer. The first hatch, during the last week of May, consisted of three or four species of midges (Chironcmidae), and at least two species of sciarids (Sciaridae). The second hatch, by far the largest, occurred during the last week of June and first week of July. At least two species of mayflies (Ephemeridae and Heptageniidae), two or three species of midges (Chironomidae), and two or three species of caddisflies (Helicopsychidae and Hydropsychidae) constituted the majority of the hatch. The third hatch took place during the last week of June. Caddisflies (Helicopsychidae), were the principle insect of the hatch and were found primarily on the southeast side of the island.

Dipterans accounted for a total of 78% of all terrestrial arthropods taken. The families Chironomidae and Sciaridae were the most abundant and comprised 52% of the total (by number). The orders Homoptera and

Hymenoptera contributed to 6% and 5% of the total, respectively. The Ephemeroptera, although contributing to only 2% of the total sample, contribute the majority of biomass during the second insect hatch on the island.

Amphipods, copepods, and cladocera were the most abundant of potential aquatic food items and constituted 78% of the total (by number). Other aquatic organisms were much less frequent.

Aquatic organisms were abundant earlier than were adult insects. Territories which were best for this early aquatic food were not the same as those ideal for adult insects at the time of chick growth.

Distributions of aquatic and terrestrial food items were not random, but wind dependent. Wind speeds of greater than 10 mph resulted in reduced trap catches with sheltered shorelines and trap areas typically exhibiting highest trap catch. Overall trap catch was lowest during northerly winds.

Vegetational characteristics of each area interacted with winds of different directions and velocities and resulted in localized concentrations of insects. Effects of vegetation were twofold, woody vegetation provided maximum shelter from the wind for imagos during mating flights and resulted in accumulations, whereas dense herbaceous ground cover inhibited insect activity and reduced trap success.

The great extent of semi-open beach habitat was an important attribute of the southeast beach. Birds resident there spent less of their time foraging on open beach even though insect catch was highest in

open beach sites. Woody vegetation of varying heights on beach ridges may serve to concentrate insect mating flights throughout the semi-open beach habitat. Insect availability, highest on the southeast beach, could explain why large numbers of birds compete for territories there.

Percentages of time spent foraging on open beach habitat and total time on open beaches did not show differences in male and female usage. Peck rates were comparable for different beaches and during periods of low insect abundance were two to three times those observed when food levels were high. Birds exhibited feeding behavior indicating high specificity when insects were abundant and low specificity when food levels were low. Observations of females showing preferential feeding behavior during periods when insects were plentiful may indicate that females are utilizing a specific food item high in calcium content.

Nest initiation dates and projected hatching dates were correlated with the two largest insect hatches on the island. Thirteen of 14 females initiated nests during a six-day period following the first major hatch. Projected hatching dates of those nests indicate that chicks of first clutches would have hatched just prior to the second and largest insect hatch.

APPENDICES

APPENDIX I

STICKY TRAP SAMPLES

Sample Composition

Order-Family	Number Organisms	Percentage
Diptera	1939	77.56
Chironomidae	971	38.84
Sciaridae	331	13.24
Phoridae	147	5.88
Simuliidae	130	5.20
Dolichopodidae	69	2.76
Sphaeroceridae	51	2.04
Chloropidae	48	1.92
Muscidae	28	1.12
Mycetophilidae	19	.76
Sciomyzidae	17	.68
Piophilidae	15	.60
Ceratopogonidae	10	.40
Ephydridae	10	.40
Anthomyiidae	10	.40
Tipulidae	10	.40
Heleomyzidae	10	.40
Psychodidae	9	.36
Scatopsidae	8	.32
Culicidae	6	.24
Psilidae	5	.20
Empididae	5	.20
Lonchopteridae	4	.16
Calliphoridae	4	.16
Lonchaeidae	4	.16
Tachinidae	3	.12
Tabaniidae	2	.08
Lauxaniidae	2	.08
Stratiomyidae	2	.08
Micropezidae	2	.08
Dryomyzidae	2	.08
Chamaemyzidae	1	.04
Asilidae	1	.04
Pipunculidae	1	.04
Ptychopteridae	1	.04
Dixidae	1	.04

Order-Family	Number Organisms	Percentage
Trichoptera	140	5.60
Helicopsychidae	73	2.92
Hydropsychidae	48	1.92
Limnephilidae	8	.32
Leptoceridae	6	.24
Hydroptilidae	2	.08
Psychomyiidae	1	.04
Phryganeidae	1	.04
Molannidae	1	.04
Homoptera	149	5.96
Cycadellidae	144	5.76
Aphididae	2	.08
Membracidae	3	.12
Hymenoptera	124	4.96
Braconidae	46	1.84
Pteromalidae	28	1.12
Ichneumonidae	16	.64
Formicidae	9	.36
Diapriidae	5	.20
Scelionidae	5	.20
Encyrtidae	4	.16
Myrmaridae	4	.16
Platygasteridae	3	.12
Ceraphronidae	1	.04
Roproniidae	1	.04
Torymidae	1	.04
Tenthredinidae	1	.04
Ephemeroptera	57	2.28
Ephemeridae	45	1.80
Heptageniidae	12	.48
Coleoptera	36	1.44
Chrysomelidae	8	.32
Staphylinidae	6	.24
Coccinelidae	5	.20
Pselaphidae	3	.12
Dermestidae	3	.12
Anthicidae	2	.08
Byrridae	2	.08
Cryptophagidae	1	.04
Carabidae	1	.04

Order-Family	Number Organisms	Percentage
Coleoptera (Continued)		
Elateridae	1	.04
Lampyridae	1	.04
Orthopteridae	1	.04
Silphidae	1	.04
Collembola	24	.96
Entomobryidae	13	.52
Isotomidae	8	.32
Sminthuridae	3	.12
Thysanoptera	5	.2
Thripidae	5	.2
Orthoptera	4	.16
Acrididae	3	.12
Gryllidae	1	.04
Lepidoptera	2	.08
Olethreutidae	2	.08
Hemiptera	3	.12
Hydrometridae	1	.04
Saldidae	1	.04
Phymatidae	1	.04
Neuroptera	3	.12
Sialidae	3	.12
Psocoptera	4	.16
Psocidae	4	.16
Araneida	9	.36
Thomisidae	6	.24
Amaurobiidae	2	.08
Pholcidae	1	.04
Odonata	1	.04
Coenagrionidae	1	.04

APPENDIX II

SHORELINE SAMPLES

Sample Composition

Group	Number Organisms	Percentage
Phylum Nematodea	11	.16
Phylum Nematomorpha	5	.07
Phylum Annelida		
Class Oligochaeta	90	1.32
Class Hirudinea	15	.22
Phylum Mollusca		
Class Gastropoda	24	.35
Phylum Arthropoda		
Class Eucrustacea		
Subclass Branchiopoda		
Order Cladocera	2197	32.27
Subclass Copepoda	785	11.52
Subclass Malacostraca		
Order Amphipoda	2378	34.92
Class Insecta		
Order Psocoptera	4	.06
Order Hymenoptera	7	.10
Order Hemiptera	153	2.24
Order Homoptera	21	.31
Order Odonata		
Larvae	1	.01
Order Plecoptera		
Larvae	3	.04
Order Trichoptera		
Larvae	17	.25
Adults	6	.09
Order Ephemeroptera		
Larvae	368	5.40
Adults	15	.22
Order Diptera		
Larvae	384	5.64
Adults	310[a]	4.55
Order Coleoptera		
Larvae	1	.01
Adults	8	.12

Group	Number Organisms	Percentage
Class Arachnida		
Order Acari	2	.03
Order Araneae	5	.07

[a] 83% Chironomidae

APPENDIX III

COMMON HERBACEOUS PLANTS

Alismataceae
- *Sagittaria latifolia*

Convolvulaceae
- *Convolvulus sepium*

Caryophyllaceae
- *Silene* spp.

Rubiaceae
- *Galium* sp.

Apocynaceae
- *Apocynum cannabinum*

Hydrophylaceae
- *Hydrophylum virginianum*

Balsaminaceae
- *Impatiens* sp.

Onagraceae
- *Oenothera* spp.

Euphorbiaceae
- *Euphorbia esula*

Polygonaceae
- *Polygonum* spp.

Verbenaceae
- *Verbena hastata*

Papaveraceae
- *Corydalis* sp.

Asclepiadaceae
- *Asclepias purpurascens*

Leguminosae
- *Lathyrus japonicus*
- *Vicia americana*

Chenopodiaceae
- *Chenopodium* sp.

Campanulaceae
- *Campanula* sp.

Nyctaginaceae
- *Mirabilis nyctaginea*

Labiatae
- *Mentha* sp.
- *Scutellaria* sp.

Urticaceae
- *Urtica dioica*

Typhaceae
- *Typha latifolia*

Compositae
- *Achillea millefolium*
- *Solidago* spp.
- *Cirsium* sp.
- *Aster* spp.
- *Bidens* sp.

Rosaceae
- *Potentilla* sp.
- *Geum* sp.

Umbelliferae
- *Circuta* sp.

Violaceae
- *Viola* spp.

Cruciferae
- *Brassica* sp.

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